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SCIENCE ABSTRACTS.

Section A.—PHYSICS.

JUNE 1917.

GENERAL PHYSICS.

440. *Mechanism for Tracing the Hodograph of Projectiles.* **J. Olive.** (Comptes Rendus, 164. pp. 97–99, Jan. 8, 1917.)—Consideration of the equation of the hodograph corresponding to the motion of a projectile shows that it can be traced by a rolling wheel subject to certain defined constraints. An instrument based on this theory is described and a diagram given. Having traced the hodograph with the instrument, mechanical quadrature is employed to determine a series of points on the trajectory of the projectile. The instrument will probably prove of considerable service in determining the trajectories for new forms of projectiles experiencing a modified air-resistance, which would render the usual tables inapplicable. A. W.

441. *Comparison of the Utrecht Pressure Balance of the van't Hoff Laboratory with those of the van der Waals Fund at Amsterdam.* **E. I. Hoogenboom-Smid.** (K. Akad. Amsterdam, Proc. 19. 4. pp. 649–652, 1917.)—In the former half of 1915 a comparison was made of the small Amsterdam pressure balance with the open standard manometer at Leiden from 20 to 100 atmos. [See Abs. 269 (1916).] The result of this was that the effective area appeared to be not equal to the real area ; a constant value was not even found, but a value dependent on the pressure. The author has made a study of the theory of the instrument, investigating whether the deviations of the effective area from the real area presented the same course for different pressure balances. A comparison was made of the Utrecht pressure balance with the small and large pressure balances at Amsterdam, tables being given. The following remarks are made : (1) The height of the piston appears to have an appreciable influence on the pressure. This influence was not observed at Leiden in experiments made expressly for the purpose. (2) The rotatory velocity has an appreciable influence on the pressure. (3) The direction of rotation has a great influence on the pressure with the Utrecht pressure balance, and, when the charge is very slight, rotation can only take place in one direction. The result found is that the ratio of the effective areas appears to be pretty well constant, taking into consideration the inaccuracy which is the consequence of the phenomena

mentioned in the above remarks. On comparison of the Utrecht pressure balance with the small Amsterdam balance, however, the ratio values seem to present a slight systematic course. Further work is promised.

H. H. Ho.

442. *Pantograph Planimeter.* **A. Klingatsch.** (Zeits. Instrumentenk. 37. pp. 25–32, Feb., 1917.)—Instruments of this type have previously been described by Doležal and by Eggert. The present paper gives the details and theory of action of an improved form giving considerable accuracy.

A. W.

443. *Standard Density and Volumetric Tables.* (Bureau of Standards, Circ. No. 19 [5th Edition, 65 pp.], Washington, 1916.)—In this circular are presented density and volumetric tables for certain substances much used in the arts and sciences, for example : water, ethyl alcohol, methyl alcohol, sulphuric acid, and cane-sugar solutions. Tables of data useful in the calibration of hydrometers and volumetric apparatus are also included.

L. H. W.

444. *Testing of Glass Volumetric Apparatus.* (Bureau of Standards, Circ., No. 9 [3rd Edition, 32 pp.], Washington, 1916.)—This circular contains specifications and tolerances for glass volumetric apparatus, such as burettes, cylindrical graduates, flasks, pipettes, Babcock test bottles, and specific gravity flasks for Portland cement, and also a short description of methods of test of this apparatus. The circular is of interest to manufacturers and users of volumetric apparatus. L. H. W.

445. *Damping of Disturbances in Mercury.* **M. H. Stillman.** (Bureau of Standards, Bull. 13. pp. 563–568, 1916.)—It is sometimes of great importance that the mercury in certain instruments be prevented from freely vibrating under the actions of a disturbing force, and this is especially true when the mercury is used in mercurial barometers. It was found that the disturbances in the mercury are practically eliminated if it is subjected to a strong magnetic field, *e.g.* by placing it in certain positions between the poles of a strong magnet. L. H. W.

446. *On Graphical Representation by Means of Curves.* **H. Schwerdt.** (Phys. Zeits. 18. pp. 45–53, Feb. 1, 1917.)—A common practical exercise is the graphical representation of the connection between several magnitudes mutually dependent. The present author first deals with ordinary graphical methods, and then proceeds to develop a new method for the preparation of data curves. Every relation $F(x,y,p) = 0$, is indicated in the rectangular Cartesian system of coordinates (x,y) as a curve referred to the parameter p. This (x,y) plane may then be represented on a (ξ,n) plane, and for the case of geometrical anamorphosis the important advantage is attained that the representation is bound up with the choice of a single function ; many examples of ordinary multiplication are given in illustration. General anamorphosis is elucidated by a new table of parabolas.

The paper contains twelve diagrams. H. H. Ho.

447. *Determination of the Density of Solids.* **H. le Chatelier** and **F. Bogitch.** (Comptes Rendus, 163. pp. 459–463, Oct. 30, 1916.)—The authors

point out the very considerable divergence between the values of the density of solids given in the literature. They consider that the most important source of error in the determinations is the adhesion of a thin layer of air to the surface of the immersed solid. On carrying out a number of determinations of the density of a few solids immersed in different liquids, they find that when water is employed the errors in the determinations are very considerable, but when benzene, mineral spirit, or carbon tetrachloride is employed, the values are concordant to within 0·06 %. Water, therefore, should never be used for the immersion of solids in determinations of the density. A. F.

448. *Direct Measure of Axial Speed of Water in Fizeau's Experiments.* **P. Zeeman.** (Comptes Rendus, 163. pp. 235–236, Sept. 4, 1916.)—In this experiment it has been customary to infer the axial speed from the mean by the calculated relation that the latter was 0·84 of the former. But there is uncertainty in this numerical coefficient. Hence the author devised a direct optical method of measuring the axial speed. This was effected by the introduction of some small air-bubbles into the water. By a window in the wall of the tube these bubbles are observed to appear as bright lines on a black ground. It is thus found that the axial speed varies from point to point along the tubes and that observations are needed at a number of points from which a mean axial speed can be derived. This was found to be 550·8 cm. sec.$^{-1}$. This only differs by 0·5 % from the value previously used. E. H. B.

449. *Systematic Variation of Value of the Kinetic Energy in Elastic Impact of Bodies.* **L. Hartmann.** (Comptes Rendus, 163. pp. 559–562, Nov. 13, 1916.)—Experimental results are given in confirmation of previous work [Abs. 1254 (1916)], and further examples are deduced to show that, in the case of elastic impact of steel cylinders, one of which is at rest before impact, the difference of the kinetic energy before and after the impact, and the heat evolved, are not equivalent. The amount of this discrepancy is shown to depend not only on the velocity of impact, but also on the substance of which the cylinders are composed. On the other hand, it is concluded that the total momentum of the impinging masses is effectively conserved.

(Ibid. pp. 94–96, Jan. 8, 1917.)—The object of this second note is to show experimentally that the kinetic energy is not conserved in the impact of two bodies both of which may be moving before impact. The total energy is always smaller than before the blow, this difference systematically increasing with increase in the value of $V - V'$, V and V′ being the initial velocities of the impinging masses. This is most easily verified in the case of two identical cylinders having initially equal and opposite velocities. In this case the kinetic energy is reduced from $2mV^2$ to a smaller value $2mV^2(2n-1)^2$, where the value of n is found to be a function of that of V. In every case, however, there is effective conservation of the quantity of momentum, conformably with the conception of Descartes. T. B.

450. *Comparison of a Certain Case of the Elastic Curve with its Approximation.* **R. W. Burgess.** (Phys. Rev. 9. pp. 193–197, March, 1917.)—In the usual discussion of the elastic curve in elementary text-books of physics and engineering, a certain term in the differential equation of the curve is neglected and the curve resulting from this approximation is said to be a good substitute for the real elastic curve. It is the present author's purpose to show by a comparison of one case of this approximate solution with the

accurate solution, that the one is not always a satisfactory substitute for the other. A straight thin rod is considered, bent into a bow by two opposing equal forces acting at the ends, and the error of the usual solution shown to be nearly 100 %. The author concludes that the cosine curve $y = h \cos x/a$, with h determined by a formula deduced from this equation, is not satisfactory as an approximate solution, in any case where the length of the bow or column is one of the physical constants. The difficulty is due to the fact that the deflection is of the same order of magnitude as the slope, which has been considered negligible. Errors of this nature, due to dropping terms from a differential equation, probably exist in other physical problems; the present case is unusual in that both the exact and the approximate equations can be solved in terms of known functions. H. H. Ho.

451. *Report of the Hardness Tests Research Committee.* (Inst. Mech. Eng., J. No. 9. pp. 677–712, Dec., 1916, and No. 1. pp. 713–724; Disc., 724–778, Jan., 1917. Engineering, 102. pp. 556–558, Dec. 8, and pp. 597–599, Dec. 15, 1916. Mech. Eng. 38. pp. 497–501, Dec. 29, 1916, and 39. pp. 4–7, Jan. 5, 1917.)—The various methods which have been devised for testing hardness fall into one of two categories: (1) abrasion tests, and (2) indentation tests. Applied to pure metals in their normal states the various tests give results which are in approximate agreement, but in the case of alloys subjected to mechanical or thermal treatment comparison is impossible. A series of comparisons of the results of hardness and wearing tests (rolling abrasion) of material whose composition and thermal and mechanical conditions of production extended over a wide range have been made by Stanton and Batson. A Wöhler fatigue-testing machine was adapted for wear tests by the Saniter method, the tests being carried out on 1-in. diam. specimens rotating at 2200 revs. per min. in a 1½-in. diam. ring under a load of 410 lbs. The wear was taken as the reduction in diam. in ten-thousands of an inch after 200,000 revs. of the specimen. The resistance to wear was taken as one thousand times the reciprocal of this number. Plotting the results of the ball-hardness tests as functions of the results of the rolling abrasion tests shows that for hardened and tempered steels the resistance to rolling abrasion is proportional to the ball-hardness number. In Mn steels the ratio of the abrasion resistance to hardness is very high. After the rolling test the scleroscopic hardness of the surface of Mn steels was found to be doubled. The method of test was found to be rapid and satisfactory so long as precautions were taken to fix the axis of the specimen accurately in line with the axis of rotation of the chuck and the wearing ring was renewed frequently. By means of an Oldham coupling both the specimen and the wearing ring were caused to rotate simultaneously, so that the ring did a certain amount of slipping over the specimen, and a new type of test, called a sliding abrasion test, was obtained. This test revealed little or no evidence of the gradual hardening of the surface undergone by some materials in the rolling test. This means that as the test proceeds it is made continually on material in its original state, and not on deformed material. The general conclusions of the investigators are that the Brinell hardness numbers of a miscellaneous selection of steels are not a safe guide in predicting their relative resistance to wear. In appendices, **W. C. Unwin** describes briefly the various methods which have been evolved for determining hardness and resistance to wear; **R. A. Hadfield** sums up hardness as generally understood to be a loose term not representing any specific property, except resistance to deformation, and

points out how the various methods of measuring hardness break down in particular cases; **A. E. H. Tutton** defines hardness as the resistance offered by a smooth surface to abrasion, and is intimately connected with cohesion. In a crystalline material the hardness is always a minimum along the direction of the cleavage planes. A fourth appendix contains a very complete bibliography of the literature of the subject. In the *discussion*, **R. A. Hadfield** attributed the wear-resisting qualities of Mn steel to the fact of its hardening under deformation, since by mere deformation the surface hardness could be increased from 200 to 500 Brinell. **E. H. Saniter** defined the properties necessary to resist wear as the resistance to distortion determined by the Brinell test, the hardness produced by distortion, which might be measured by making scleroscope tests on the original material, and also in the Brinell impression, and toughness as measured by impact tests. **F. Rogers** described his abrasion testing-machine in which the specimens, two in number, are mounted at the ends of arms revolving inside a casing containing water and coarse emery. **R. A. Hadfield** communicated the results of a large number of experiments showing the relationship between the Brinell, Shore, and Moh's scales of hardness. **H. le Chatelier** showed from a physical point of view that hardness could not be measured and that the problem was to establish two or three standard methods of reference.

F. C. A. H. L.

452. *Relationship between Stress and Resistance to Bending.* **H. Kayser.** (Zeits. Vereines Deutsch. Ing. 61. pp. 92–97, Feb. 3, and pp. 124–127, Feb. 10, 1917.)—The mathematical investigation of rods with respect to pressure can be carried out in the case of thin bars by means of Euler's equation, supplemented by Tetmayer's empirical formulæ and the pressure-curvature equations. For bars with known elasticity and constant moment of inertia the usual methods can be applied, but when the elasticity and extensibility are unknown and the moment of inertia changes, there is a decided scarcity of information available. The introduction of the breaking modulus by Engesser does not always lead to satisfactory results, since its magnitude is very uncertain. The author also remarks that at the breaking-point of the rod the separate parts of it may exhibit quite different breaking moduli, with other complex phenomena in addition. He then takes up the investigation of the relations between the bending of rods and the breaking-stress. The calculation of the degree of bending involves not only the properties of the material, but also the degree of stretching, and affords a fairly reliable means of estimating the resistance to breaking, even for rods with variable moments of inertia and unknown elasticity and extensibility. Part I of the paper considers the subject from the theoretical standpoint, the first section dealing with the simplest case of a bent rod, where it is shown that for practical purposes exact knowledge of the form of the bent rod axis is not of very great importance for the determination of the bending conditions, since, on breaking, other causes, such as difference in substance, eccentricity, magnitude of the breaking-stress, etc., play a greater part. The second, third, and fourth sections deal with the bending resistance of straight rods under different loading conditions. Section 5 summarises the results, and deals with the practical application of the formulæ established. The author points out that the determination of the bending resistance is of the greatest importance for the calculation of pressure rods. Two equations must be satisfied, viz. $nP = R$ and $\sigma = P/F \pm R/(R - P) \cdot f_0 P/W$, where P is the pressure, n the degree of stability, σ the allowable marginal pressure of the

cross-section, F the area of the cross-section, W the moment of the resistance, and f_0 the initial bending of the rod's axis. The pressure is therefore only a fraction of the bending resistance. A detailed discussion is given of these formulæ, and the value of their application to building materials pointed out.

Part II of the paper deals with experiments designed to ascertain how far the previous formulæ may be accepted in actual practice. The first series of experiments were carried out with rods of pitch-pine, and full details of these are given, together with tables, curves, and diagrams. The second set of experiments were made with iron rods. The author claims that by his method the difficulties encountered when the elasticity and extensibility are unknown are removed, since from the magnitude of the bending for a weight acting transversely to the rod's axis the amount of the resistance to bending may be ascertained. The bending should be arrived at by experiment, although for simple cases it may be calculated. For practical purposes it suffices to study the effect of the load at the middle of the rod. The author intends to continue this line of investigation for the study of buildings, bridges, lattices, etc. H. H. Ho.

453. *Gravitation and Thermodynamics.* **P. E. Shaw.** (Nature, 99. pp. 84–85, March 29, 1917.)—G. W. Todd suggests that when one gravitative mass approaches another it acquires heat. This might occur when, as is usually (but not always) the case, the body moves up the gradient of the potential; for then the energy of field displaced by the body would increase [see Abs. 313 (1917)]. There is one development of the above speculation which is not mentioned by J. L[armor], though it may have been inferred. Suppose two cases: (*a*) A metal disc is in a vertical plane at the earth's surface. If it be started spinning on a horizontal axis through its centre, the descending half warms and expands, the ascending half cools and contracts, there will arise a turning moment, and the disc will now continue to spin of itself provided the friction is small enough. (*b*) The extreme top and the extreme bottom of the disc will be cold and hot points respectively, so that if metal brushes be applied there, we could obtain a continuous current in a closed circuit. These are two cases of perpetual motion. **O. J. Lodge.** (Ibid. pp. 104–105, April 5, 1917.)—If P. E. Shaw's contention for a perpetual motion consequence of gravitational heat were justified, it would be an argument against the supposed effect on which such a conclusion could be based; but Lodge does not allow that the contention is justified. For the line joining maximum to minimum temperature is vertical, and, unless the rate of heating differs from the rate of cooling, every horizontal chord will be an isothermal; so there is nothing to keep a vertical disc rotating. **G. W. Todd.** Todd admits that the expression previously derived needed modification, and now proposes for the attraction (assuming specific heat independent of r) the formula $F = m\theta f(r) + \psi(r)$, where m is the mass of the body at temperature θ. It is claimed that this expression has none of the objections which the previous incorrect expression had, for at the absolute zero the temperature correction vanishes and $\psi(r)$ is probably $GMmr^{-2}$. To avoid P. E. Shaw's difficulty as to perpetual motion it is proposed to make $\partial Q/\partial r$ positive instead of negative. This would not alter the expression for F, but would bring Shaw's disc to rest. E. H. B.

454. *Gravitational Attraction.* **F. H. Loring.** (Chem. News, 115. pp. 181–182, April 20, 1917.)—A semi-popular article on gravitation and its partial resemblance to magnetism. E. H. B.

455. *Cosmological Deductions from the General Theory of Relativity.* **A. Einstein.** (Preuss. Akad. Wiss. Berlin, Ber. 6. pp. 142–152, 1917.)—It is well known that the Poisson differential equation $\Delta\phi = 4\pi K\rho$, together with the equation of motion of the material point, have not completely replaced the Newtonian theory of action at a distance. The condition must still hold that in infinite space the potential ϕ tends to a definite limiting value. The general theory of relativity exhibits analogous behaviour to the theory of gravitation ; here also limiting conditions to the differential equations must exist for infinite space in the case where the universe must be regarded as capable of unlimited spacial extension. For treating the planetary problem, the author has assumed these limiting conditions to take the following shape : It is possible so to choose a system of reference that gravitational potential becomes constant at infinity. It is not, however, *a priori* evident throughout that these boundary conditions may be fixed, if only large parts of the material universe be considered. The author here gives an account of his investigations into this fundamental problem. Section I deals with the Newtonian theory ; Section II examines the boundary conditions suitable for the general theory of relativity ; Section III investigates the spacial closed universe with uniformly distributed matter. In Section IV an additional term to the field equations (gravitational) is considered. In Section V the determination is completed and a result given. The theoretical conception of the real universe consequent on the results obtained is that the curvature of space is variable according to the distribution of matter, but approximates for the greater part to a sphere. At all events this conception is logically free from objection, and also the best from the standpoint of the general theory of relativity. Whether it be tenable in the light of our present astronomical knowledge has not been investigated. To arrive at this conception a new extension of the field equations of gravitation has to be made. If an additional term be not introduced into the latter then a positive curvature of space results. The term is necessary to render possible a quasi-statical distribution of matter corresponding to the fact of small star velocities. [Abs. 853 (1916) should also be consulted.] H. H. Ho.

456. *Dynamic Pressure on Submerged Flat Plates.* **H. E. Stevens.** (Am. Soc. Mech. Eng., J. 39. pp. 318–320, April, 1917.)—The object of this investigation was to find an equation expressing the relation between the velocity of a stream and the resulting pressure on a submerged flat plate held at right angles to the direction of flow. Experiments were conducted with the plate at different depths below the surface in order to establish whether this affects the equation. The effect of varying the area and shape was determined, and one plate was used only partially submerged to ascertain whether the same equation would hold. The article gives diagrams and full explanation of the apparatus used. The equation was found to be : $P = AV^2(0{\cdot}6A + 1{\cdot}25)/D^{0{\cdot}1}$, where P = total pressure on plate in lbs. ; A = area of plate in sq. ft. ; V = velocity in ft. per sec. ; D = depth of centre of plate below surface in ft. W. J. C.

457. *Calculating the Resistance in a Confined Fluid Current.* **H. Villat.** (Comptes Rendus, 164. pp. 275–278, Feb. 5, 1917.)—The author has previously investigated the motion of a fluid current limited by a boundary parallel to the general direction of the stream, when this strikes against a given obstacle. The present note is to make an important amplification of the

above. One of the essential features of the method employed is the representation of the region occupied by the fluid when in motion upon half of the area comprised in a plane $\zeta \times \xi + i\eta$ between two circumferences of radii q (< 1) and unity. Conforming to the author's previous notation the components of the resistance P_x, P_y, experienced by the immersed solid satisfy the relation : $P = P_x + i P_y = 1/2i \int_{|\zeta|=1} e^{i\Omega} df$. The author has previously determined the limits between which these components are valid, and now attempts to prove that the component P_x, which is directly opposed to the motion, may always be calculated explicitly without having recourse to quadrature. The conclusion is drawn that the direct resistance P_x is positive and never zero for any convex obstacle opposed to the current. An important application to the case of a rigid plane plate forming an obstacle normal to the fixed boundary is then described. By utilising these results, the pressure exercised by the fluid upon a plate of given dimensions may be determined at any given distance from the boundary. Interesting comparisons may now be made with the theoretical results found when the fluid is not confined by any boundary, and where the direct resistance has a smaller value than that found experimentally. An interesting geometrical consequence is pointed out, namely, that by symmetry in relation to the fixed boundary the obstacle exercises a doubled effect. H. H. Ho.

458. *Anomalies in Wave Kinematics and their Solution.* I. **K. Uller.** (Phys. Zeits. 18. pp. 99–100, March 1, 1917.)—The proof of the existence of a field of the wave normal couple in a scalar or vectorial wave of elementary vibration form, affords proof also of the irreversibility of this wave, *i.e.* if the couple be reversed the wave will not travel in the same form backwards, and, in general, not along the same path. The author, after some discussion, states that propagation phenomena in fields not specially defined are irreversible. This also holds for any substance acting as medium for the wave propagation, both for the case when the wave energy is unattached and also under conservative conditions. This result is in contradiction to a hitherto accepted condition, viz., that waves traversing under conservative conditions are reversible, and that the Maxwell-Hertz media field-equations remain unchanged. From the latter property it follows that if during any electromagnetic process in conservative substances the magnetic field strength is suddenly reversed throughout while the electrical field retains its value, the whole process must run in a reversed direction. This contradiction is solved if of the two possible reversible changes in space and time the latter, which exists only in the imagination, be ignored. The author considers the general case when time is included, and arrives at the conclusion that even in imaginary experiments, just as in material nature, the time can only increase. He next examines the above question from the standpoint of Newtonian mechanics, arriving at the same result with respect to time. On further examination the author regards the equations of classical mechanics as degenerated pressure equations. Various kinds of waves are examined and their anomalies similarly explained. H. H. Ho.

459. *The Interference Principle.* **K. Uller.** (Phys. Zeits. 18. pp. 101–103, March 1, 1917.)—The stationary stream picture, afforded by two stationary sources in a fluid external to these is a complete entity at every point. Two different phenomena cannot then be perceived as emanating from the sources. It is otherwise if the sources change with time, as in this case two

sets of phenomena and two sources can be recognised. No matter how the variations occur, two sets of propagation occur which inter-penetrate, *i.e.* interfere. In a non-stationary field the interference principle rules, which must be distinguished from the principle of superposition, being a purely kinematic principle as distinct from a physical process which has a definite value in nature. The author considers it remarkable that this principle should not have received adequate mathematical attention hitherto. He finds that in scalar or vector waves of elementary vibration form, there exists the field of a time-invariable vector couple of the wave normal couple, independent of the wave scalar or vector respectively. The latter he proves mathematically to be a universal principle. After some discussion the following kinematical law for waves of elementary vibration form is stated : Waves cannot be superposed on a single wave, while single waves cannot be split up into other waves. The first principle enunciated above is then shown to be the kinematical expression of the interference principle. The second principle is next shown to be the kinematical expression for waves of any vibration form, and is the extension of the first to waves in general. It is found, as a consequence, that the wave normal couple can never be added to that of another wave, and, conversely, a couple can never be split up into other wave-normal couples. Waves have thus the characteristics of individuals, and only are capable of interference. Young's interference principle based upon superposition without disturbance is thus shown to be fallacious. It follows that the irreversibility of every propagation phenomenon which possesses general motion, is a consequence of the interference principle and thereby independent of the nature of the process. H. H. Ho.

460. *Recent Developments in Molecular Physics.* **J. H. Jeans.** (Engineering, 103. pp. 354–355, April 13, 1917. Paper read before the Royal Inst.)—The subjects dealt with are The Theory of Relativity and The Law of Equipartition of Energy. The former accounts for the negative result of every attempt to obtain experimental evidence of the earth's drift through the ether by the assumption that it is an essential impossibility to measure the movement of any portion of matter except relatively to that of some other portion. Incidentally, it makes the existence of the ether a matter of indifference. But it solves some difficulties. For Einstein has derived, on the basis of this theory, an explanation of gravitation, according to which the law of inverse squares is merely a first approximation ; and it accounts so well for the observed secular motion of the nodes of a planetary orbit in the direction in which the planet is moving that, in the case of the planet Mercury, Einstein's calculated value is 42·9 seconds of arc per century, while the observed value is 43 seconds.

The equipartition law, according to which the energy gained or lost by any system of bodies capable of moving in different ways, including movements of vibration and rotation, as the result of any disturbance to the system, will, after the subsidence of the disturbance, be equally distributed amongst the various degrees of freedom of the system, appears to be applicable to all solid bodies and also to molecules and atoms, but not to electrons. If it were applicable also to electrons, the atomic heat of all solids should be identical, and independent of the temperature. But recent low-temperature researches have shown that this constancy is apparent only at ordinary temperatures in the neighbourhood of 300° abs. As the temperature falls below 200° abs., the atomic heat decreases more or less rapidly at first, and, finally, very slowly as the absolute zero is approached. By suitably adjusting the several scales of the observed curves obtained for a number of substances P. Debye found that

they all became reconciled into a common curve coinciding with the theoretical curve deduced from Planck's formula for the radiation of a hot body, obtained by him on the basis of his *quantum* hypothesis, that absorption and emission of energy take place, not continuously, but in jumps such that the quantity absorbed or emitted is always a multiple of $h\nu$, where h is a universal constant, not varying with the substance, and ν is the frequency of vibration of the radiation. The specific heat of a chemical element then appeared as a function of T/θ, where T is the absolute temperature of the element in question, and θ is a temperature characteristic of the element and is calculable from its elastic constants. T/θ was then equal to $1/x$, where $x = h\nu/RT$, R being the gas-constant. The total heat energy of a solid could then be estimated from a knowledge of the specific heats at all temperatures, and this energy was exactly accounted for by assigning an average value of $RTx/(e^x - 1)$ to each elastic vibration of a solid. From these results it follows that Newton's laws of motion, on which the equipartition theory is based, do not hold for low temperatures and high frequencies. The x became small for small ν and high T, giving the equipartition law; but for low T, x was very large, and the energy per degree of freedom became very small, as the study of black-body radiation had shown. Moreover, Poincaré has shown that the experimental curves directly lead to the formula $RTx/(e^x - 1)$, and this in its turn to the quantum theory, Planck's derivation of which has been objected to. This quantum theory successfully accounts for photoelectric and allied phenomena, and, in the hands of N. Bohr and J. W. Nicholson, has thrown much light on atomic constitution and the structure of spectra, but it also leads to fresh difficulties and has not yet been shown to be reconcilable with optical phenomena such as interference and diffraction, which appear to demand the continuous wave-fronts of the ordinary undulatory theory. G. W. DE T.

461. *The Measurable Quantities of Physics.* **R. C. Tolman.** (Phys. Rev. 9. pp. 237–253, March, 1917.)—As any branch of science develops, its considerations become more and more deductive in their nature, the ideal form of scientific exposition apparently being one in which all the important relations are logically derived from a small number of independent general principles or postulates and all the terms used are defined with the help of a small number of indefinables. (The term indefinables is here used in its technical sense, and by it is to be understood certain entities which are not defined in the particular discussion undertaken but for the purposes at hand are assumed rather to be matters upon which there is general agreement. This does not of course in any way prejudice the possibility or desirability of their definition in some more fundamental treatment.) The time is already ripe for a much more comprehensive and systematic treatment of the field of mathematical physics than has hitherto been attempted, and the completion of this task would make it possible to derive all the equations of mathematical physics from a few consistent and independent postulates, and to define all the quantities occurring in these equations in terms of a small number of indefinables. The purpose of the present paper is to discuss from a somewhat general point of view the nature of the quantities which occur in the equations of mathematical physics and to consider a set of indefinables for their definition. It is hoped in this way to help in the preparation for that more complete systematisation of mathematical physics which is surely coming.

It will thus be found possible (in accord with the work of others) to distinguish two general classes of quantity, namely, those having *extensive* and

those having *intensive* magnitude, and the methods necessary for measuring these two quite different kinds of magnitude are considered. In a subsequent discussion of the method of choosing a set of fundamental kinds of quantity, which will serve as indefinables for defining all other kinds of quantity, it is shown that the *number* of independent kinds of quantity which must be taken as fundamental is apparently independent of the particular set that is chosen. Contrary to previous practice, however, it is found desirable to choose as fundamental only quantities which have extensive magnitude, since we are then able to introduce a number of important simplifications. It is also found necessary to have a set of indefinable operations for use in the definition of quantities; these are briefly considered together with the definitions obtained by their help. The choice of units for the measurement of the different kinds of quantities is then considered, also the impossibility of reducing the number of fundamental kinds of quantity.

Quantities are regarded as magnitudes which have been particularised by the specification of spacial or temporal conditions. Thus the statement of the temperature in a particular beaker at a particular time is a quantity, this quantity having a definite magnitude as one of its attributes. Thus magnitude is a more abstract conception than quantity.

The distinction between the two kinds of quantity, those having *extensive* and those having *intensive* magnitude, can be made clearer by examples. Volume is typical of quantities having extensive magnitude. A given volume may be regarded as composed of smaller volumes into which it can be divided mentally, and, similarly, quantities of length, mass, energy, entropy, etc., will be seen to have extensive magnitude; temperature, density, magnetic permeability, dielectric inductivity, etc., are quantities which we cannot successfully regard as being the sum of smaller quantities of the same kind, and such quantities are said to have intensive magnitude.

In order to decide whether a given quantity has extensive or intensive magnitude it is sometimes helpful to see if the simultaneous presence of two systems, each having a definite quantity of the kind in question, can be regarded as giving a larger system with twice the quantity; if so, that kind of quantity has extensive magnitude. Thus a system of two pieces of platinum, each having a mass of 10 gm., gives us a larger system of mass, 20 gm.; hence mass has extensive magnitude. On the other hand, if each piece of platinum had a temperature of 100° abs. we should not say that the temperature of the total system was 200°, but only 100°; and accordingly temperature has intensive rather than extensive magnitude. Again, two pieces of platinum, each of density 21 gm. cm.$^{-3}$, does not give a larger piece of density 42 gm. cm.$^{-3}$, so density also is a quantity having intensive magnitude.

As to fundamental and *derived* quantities, the *dimensional formula* of a quantity may be regarded as a shorthand statement of the *definition* of that kind of quantity in terms of the kinds of quantity chosen as fundamental, and hence also as a *partial* statement of the *physical nature* of the quantity in question.

In the choice of a set of fundamental kinds of quantity, it is held desirable to keep in mind the following considerations, namely: (1) that the number of kinds chosen shall be *sufficient* but *not redundant* for the part of physical science to be handled: (2) that *all* of the kinds chosen as *fundamental* shall have *extensive* magnitude; and (3) that the choice shall be such as to further the requirements of simplicity.

For the body of physics which is at present well established we seem to need *five* kinds of fundamental quantity for defining all the quantities in use.

The ones usually chosen for this purpose are those of length l, time t, mass m, permeability μ, and temperature T, though, as shown later, a somewhat different set would be more satisfactory.

The reason that just five different kinds of fundamental quantity are necessary seems to be because the science of physics is at the present time considering five fundamentally different kinds of *thing*, namely: space, time, matter, electricity, and entropy (or *degree of run-downness*). The nature of these different kinds of "thing" will perhaps be clearer if it is noted that it is possible to arrange the physical sciences in a hierarchy such that each successive member introduces the consideration of one additional kind of *thing*. Thus *geometry* considers space only, *kinematics* (the science of moving points, lines, planes, etc.) needs the further "thing" time, *mechanics* (treating of bodies) introduces the new "thing" matter, *electrodynamics* (discussing the further laws of motion when the bodies may carry electric charges) introduces electricity, while *thermodynamics* (which deals with systems of so many parts that the individuals cannot be separately considered but only the statistical result of their interactions) introduces the new "thing" entropy or "degree of run-downness."

The desirability that all the fundamental quantities should have extensive magnitude leads the author to the rejection of permeability and temperature. For these he substitutes *quantity of electric charge* and *entropy* respectively. These also satisfy the third criterion of simplicity, which includes (1) that the fundamental kinds of quantity should be psychologically simple to grasp, (2) that they should permit straightforward definitions of the desired derived quantities, and (3) that they should bear as simple a relation as possible to the five different kinds of "thing" already referred to. On this scheme the following table of quantities and their dimensions is drawn up :—

Quantity.	Dimensions.	Quantity.	Dimensions.
Geometrical—		*Electrical—*	
Length, l_1	l	Charge, e	e
Area, A	l^2	Potential	$ml^2t^{-2}e^{-1}$
Volume, V	l^3	Capacity	$m^{-1}l^{-2}t^2e^2$
Angle	l^0	Inductivity, K	$m^{-1}l^{-3}t^2e^2$
Kinematical—		Current, I	$lt^{-1}e$
Time, t	t	Resistance, R	$mlt^{-1}e^{-2}$
Velocity, v	lt^{-1}	Electric field, E	$mlt^{-2}e^{-1}$
Acceleration, a	lt^{-2}	Magnetic field, H	$l^{-1}t^{-1}e$
Mechanical—		Magnetic pole, M	$ml^2t^{-1}e^{-1}$
Mass, m	m	Permeability, μ	mle^{-2}
Density	ml^{-3}	Magnetic induction, B	$mt^{-1}e^{-1}$
Momentum, M	mlt^{-1}	*Thermodynamical—*	
Force, F	mlt^{-2}	Entropy, S	S
Energy, U	ml^2t^{-2}	Temperature, T	$ml^2t^{-2}S^{-1}$
Energy density, u	$ml^{-1}t^{-2}$	Specific heat	$m^{-1}S$
Pressure, p	$ml^{-1}t^{-2}$		
Elasticity of compression $E = \frac{V dp}{dV}$	$ml^{-1}t^{-2}$		

Reference is made to the author's principle of similitude and the criticisms of it by Bridgman, but it is contended that the principle does contain elements foreign to the theory of dimensions.

The subject of the future developments of physical science is also discussed, as well as the possible need of adding to the present five fundamentals. E. H. B.

462. *An Atomic Model.* **L. Zehnder.** (Deutsch. Phys. Gesell., Verh. 18. 4. pp. 134–148, 1916.)—Finding difficulties in accepting Bohr's atom, especially because charges much smaller than the normal e seem to occur (Ehrenhaft), and considering that electrons seem to behave both as perfectly elastic and as inelastic bodies (Franck and Hertz), whilst O. W. Richardson regards the emission of electrons as analogous to the evaporation of solids, the author goes back to his atomic model of 1897 ("Mechanik des Weltalls"). His views presume an ether possessing structure, gravitation acting at a distance, and the possibility of a velocity exceeding that of light (Uller). The ether would be gaseous in space, but quasi-solid near celestial bodies. The atom would consist of a corpuscular nucleus, not round in general, but having corners and recesses, surrounded by ether atoms; atoms of high atomic weight would be formed by the union of smaller ones (bricks); there would be radiations from the atoms in enormous variety, and radio-activity would result, from the collision of the bricks. *Atomic Structure.* **L. Zehnder.** (Ibid. 13/14. pp. 324–332, 1916.)—A single spherical atom would be absolutely stable; but structures built up of spherical atoms need not be. The helium atom, consisting of 4 spheres in tetrahedral arrangement, would be stable, but asymmetrical with respect to any plane parallel to one of the bases, and would thus represent 4 pairs of dipoles and of electronic valencies. Twenty similar atoms would give the neon atom. Oxygen may be represented by a truncated pyramid; the two hydrogen atoms in water would not be held by the same forces. The further speculations concern carbon and carbon compounds. H. B.

463. *The Coral Reef Problem and Isostasy.* **G. A. F. Molengraaff.** (K. Akad. Amsterdam, Proc. 19. 4. pp. 610–627, 1917.)—The question of the origin of coral islands (barrier reefs and atolls) has of late been brought to the foreground again by the recent publications of Daly and Davis. According to Darwin's theory a considerable subsidence of the ocean floor over extensive areas is one of the necessary conditions for the formation of barrier reefs and atolls, and although this has well maintained itself in its main principles, yet the great crustal movements required always remain its weakest point. Depressions on such a scale hardly appear likely, though Davis considers such to be indispensable, while Daly upholds an explanation in which subsidence is not put forward as a necessary condition. The latter maintains that in the pleistocene period the storing of large quantities of water in circumpolar ice-caps must have lowered the sea-level in equatorial regions as much as 50 to 60 metres, which caused a corresponding equal lowering of the plane of abrasion and of the final base-level in those regions, whereas after the close of the glacial period a rise of the sea-level must have occurred of about the same amount caused by the melting of those ice-caps. During this last rising of the sea-level or apparent subsidence of the land according to Daly, and on account of it, the formation of the barrier reefs and atolls took place. Such fluctuations of the sea-level caused by the pleistocene glacial periods can hardly be doubted, and the Java shelf sea and Sahul bank of the East Indian Archipelago strongly supports Daly's theory. In both these cases the bottom of the sea at present gives the impression of a submerged, strongly peneplainised land-surface. Thus in Daly's glacial-control theory a fact has been brought forward for the origin of barrier reefs

and atolls, which certainly has been of primary importance for the possibility of the formation of many of these types of coral reefs, yet the present author holds that the theory is not sufficient to explain the origin of all barrier reefs and atolls. The theory gives no explanation of true or apparent subsidence of the land of considerably over 50 or 60 metres, which must be admitted to explain the formation of several barrier reefs and atolls such as those in the Pacific, since these rise individually with very steep slopes from abyssmal depths and do not stand connected with others on relatively shallow submarine platforms. True or apparent subsidence of the land of considerable amount is indispensable, in the author's opinion, for the explanation of their origin. The situation at the moment is that such subsidence either true or apparent must be assumed, although considerable diversity of opinion exists as to the amount and cause of this subsidence.

The geographical distribution of coral reefs shows that they occur in regions varying so greatly in geological structure that the causes of subsidence can hardly have been the same in all cases, *e.g.* crustal warping or folding at the coasts of continents, as in the S.W. Pacific, where subsidence in one region is more or less compensated by an upheaval in another, but other causes for true oceanic regions as in the Central Pacific and Indian Oceans where no compensation by counter-movements has taken place. Subsidence has recently been proved with certainty from borings on the island of Bermuda, which is the only oceanic island in the Atlantic lying within the limits of the geographical distribution of the reef-building corals. The borings prove this island to consist of a volcanic mountain built up of a series of superposed banks of basaltic volcanic material, the probably truncated top of which now lies somewhat more than 75 metres below sea-level. On this truncated cone or platform rests the so-called Bermuda limestone, which is a reef-limestone extending upwards to the surface of the sea. This borehole has revealed the fact that where Bermuda rises from the ocean, submarine volcanoes once were active, of which finally one or more rose above the sea ; that these volcanic islands gradually sank away and disappeared under the ocean-level since a period preceding the Eocene ; and that their subsidence for a long time has been compensated by the accumulation of successive streams of basaltic lava. The author then considers the cause of such downward movements, and opines that from the theory of isostasy some deductions may be made suggesting a possible or even probable explanation. On this theory the subsidence of the land is a real one caused by the plastic yielding of isostatically non-compensated parts of the terrestrial crust in true oceanic regions under the influence of gravity, and must be expected to occur in all true oceanic volcanic islands. This subsidence may be very considerable and will only stop when such an island has entirely or nearly sunk away into the sima of the ocean-bed or, rather, will have been recombined with it. The witness to the former existence of such an oceanic volcanic island can be an atoll rising from the bottom of the ocean to the surface. The atoll can only be formed if there is a certain ratio between the rate of subsidence of the island and the upward growth of the reefs, the latter having grown uninterruptedly during the whole period of downward movement. The above hypothesis does not give a satisfactory explanation of the upheavals which occasionally for a time interrupt the process of subsidence. In comparison with the overwhelming large number of coral islands for which no rise can be demonstrated, the cases of rising are so few that the author agrees with Darwin's conclusion that the positive movements represents oscillations only

in a direction opposite to the general downward trend. The author draws some stringent deductions which serve to test the probability of the theory. In cases where the reef-building corals have been unable to keep pace with the subsidence, corals should be obtained on deep-sea dredging, and a case of this is quoted as occurring in the Cerean Sea. According to this hypothesis deposits formed on the floor of true oceanic regions can never be definitely raised above sea-level and so partake in the building up of continents.

Recent work is summarised in an appendix. H. H. Ho.

464. *Lava Flow from Mauna Loa*, 1916. **T. A. Jaggar, Jr.** (Am. J. Sci. 43. pp. 255–288, April, 1917.)—The account here given of the eruption of Mauna Loa, Hawaii, from the flank of the mountain, relieving the congested fluids within by effervescent ejection of them through gas pressure, treats of the sequence of events at both Kilauea and Mauna Loa, 1915–16. Kilauea, 1914–16, first receives attention, a diagram being included to show the fluctuation in level of lava in the inner summit crater. The periods of premonitory seismic spasms, believed to originate on Mauna Loa, are shown in the diagram together with the gas and lava outbreaks of that volcano. A general tendency to culmination at equinox and solstice is evident throughout the chart, and this habit has proved useful in guiding expectation. The author surmises that a gas-pressure control, with release and recovery dependent on accumulation and resistance in an adjusted conduit system, is effective in inducing rhythm in volcanic mechanism. The chart shows that the Kilauea lava exhibited a spurt upward and a decline synchronous with each of the outbreaks of Mauna Loa, 1914–15 and 1916, and that just at the close of the latter outbreak the Kilauea lava column sank suddenly to profound depths. The earthquakes of 1915–16 are next described, and seismic activity coordinated with the volcanic events established. The explosion on Mauna Loa of May 19, 1916, is then dealt with in detail, including the lava outflow of May 21, 1916, and a sketch-map is given showing the lava distribution. A long narrative is quoted from the author's account of the eruption prepared on June 1. A description of Farrell's visit to the active cones on the Kona side then follows. The moving basaltic lava of the outflow was *aa*, or block lava, away from the vents, but, in the lava of stream courses close to the rift source, the surface had the ropy and membraneous character of a coarsely vesicular pahoehoe. The transition to block lava took place along the course of the flows within a few hundred yards of the source. There was gaseous explosion ejecting pumiceous fragments at the cones until the end of the eruption. The close of the eruption of Mauna Loa is next described, followed by a discussion of the great subsidence in Halemaumau. The outflow of lava in 1916 from Mauna Loa, brings to a close the eruptive period of that volcano 1914–16. Contemplation of the Kilauea diagram above mentioned leaves little doubt, to the author's thinking, that the Mauna Loa and Kilauea columns are connected, and that the connection is that of correlated gas vents and not that of hydrostatic syphon tubes. The Kilauea spurts appear to be due to gas-pressure accumulations, probably in Mauna Loa chambers, relieved by gas discharge, along with seismic jarring, at intervals, so as to induce Kilauea subsidence. The gas discharge in the larger unpluggings of the Mauna Loa rift carries magma foam with it, inducing central and summit eruption at the beginning of the eruptive period, and lateral fissure eruption at the end. Floods of highly vesicular olivine basalt accompanied both initial and final eruptions, and high fume jets initiated both outpourings. Kilauea as a decadent volcano of older origin,

acting as a gas pressure-gauge adjacent to and partially buried by the young and vigorous Mauna Loa, becomes much more intelligible than the steaming Kilauea of nineteenth-century geology. The author states that we have to thank A. Brun for inaugurating, by controversy as well as by contribution, the new conception of volcanoes as gas engines and not as steam engines.

H. H. Ho.

465. *The Turn of Tidal Streams in Relation to the Time of the Tide.* **W. B. Dawson.** (Roy. Soc. Canada, Trans. 10. pp. 71–76, Sept., 1916. Abstract.) —When the tidal undulation of the ocean enters estuaries or inlets on a coast, it not only causes a vertical rise and fall of the water surface, but also a horizontal movement of the water in reversed directions, known as tidal streams. The object of this paper is to discuss the time relations between these two movements, with illustrative examples from the Eastern and Pacific coasts of Canada, which afford a specially good field because of the great variety in their types of tide. The time relation between high water and slack water, when the tidal stream is reversed in direction in estuaries, straits, and inlets, although highly important to mariners, has hitherto received very restricted discussion, chiefly for want of a clear classification of the conditions presented by the various types of inlets and estuaries. If the tidal flow is sufficiently moderate to allow of navigation at all times, it may answer the purpose to give data for the time of max. current; but if the swiftness of the current makes navigation perilous or even impossible except at slack water, it is essential to know the time when the slack occurs, so that in solving the problem it may be either the moment of max. current or of zero current that requires correlation with the time of the tide. The author examines at some length the various characteristics of estuaries, straits, and inlets, as well as the different types in the tide itself. Of the three types of tide (Synodic, Anomalistic, and Declination), it is the declination influence which gives rise to the most striking variations. It is quite common for the time-interval to show an alternative of a full hour, on successive tides or slacks, when the moon is in high declination. In ordinary estuaries, in which the tidal undulation runs evenly, it is usual for the current to turn at a definite interval of time after high or low water. To obtain a constant time-relation, the chief proviso is that the tidal stations, to which reference is made, are suitably situated in the estuary. The complication in straits generally results from tidal undulations entering at both ends. It is remarkable to find, however, that all proximate influences may be ignored, and the behaviour of the current brought into direct relation with the moon's movements, as their primary cause. The case of narrow inlets to large areas receives very adequate examination. When a current is out of accord with the local tide it may correspond with the tide of the open ocean beyond the local channels. This is especially likely in a strait or passage behind an island, where the tide comes round both ends of the island. When the current is sufficiently moderate for navigation to be possible at all stages of the tide, the time of max. velocity may serve for practical purposes, as it may have a more constant relation to the time of the tide than slack water has. The time of the maximum can best be ascertained by current-meter observations. To obtain the differences with the time of the tide which are most nearly constant, it may be necessary to distinguish the two slack waters, or the max. velocity on the flood and ebb respectively, and to deal with these separately with reference to two different tide stations in opposite directions. When slack water cannot be brought

into a constant relation with the tide at any station that can be found, a system of variable differences must be resorted to. It may be one only of the two slack waters that this is required for. For calculation purposes a series of variable differences may give quite as accurate results as a constant difference does in other cases, as any variation from the average always recurs in some astronomical period, and the variable series represents its reduction to law. The use of such a series entails the publication of tables of slack water in full, whereas if a constant difference can be arrived at the mariner can apply this for himself to the tide tables indicated. H. H. Ho.

466. *Temperatures, Specific Gravities, and Salinities of the Weddell Sea and of the Atlantic Ocean.* **W. S. Bruce, A. King,** and **D. W. Wilton.** (Roy. Soc. Edinburgh, Trans. 51. 1. pp. 71–169, 1915.)—The hydrometric methods adopted are first described, and the remainder of the paper gives the results in the form of tables. L. H. W.

467. *On the Annual Period of Microseismic Motion.* **O. Meissner.** (Phys. Zeits. 18. pp. 73–75, Feb. 15, 1917.)—Although the daily period of the microseismic motion has received scant attention, the annual period has long been known, but has not as yet been accurately investigated. Since the monthly average of several years gives a fairly regular result, the author considers that a calculation of the harmonic constituents of the annual curve will yield reliable data. The stations utilised were Upsala, Hamburg, Potsdam, and Graz. Four tables of data are included. The annual period of the microseismic motion is found to agree excellently in phase at the above places, *i.e.* throughout the whole of North and Central Europe, showing a maximum shortly after the commencement of the year. The acceptance of a half-yearly figure improves the agreement between observation and calculation considerably, although this figure is partially dependent on locality. Also the wave period exhibits an annual course and is a linear function of the amplitude. H. H. Ho.

468. *Observations of Comet* 1915*e* (*Taylor*). **E. E. Barnard.** (Astron. J. 30. pp. 25–29, Oct. 24, 1916.)—The observations of this comet indicate that it is of short period, and that at one time in Feb. it was attended by a small companion. The original statement that it had a double nucleus is amended in the sense of definitely choosing it as a double comet. Details are given of the changes observed in the two components, resulting in the disappearance of the original comet and the survival of the companion. Comparisons are made with various other multiple comets which have been known—Brooks (1889 V), Swift (1899), Kopff (1906), Mellish (1915), Biela, the comets of 1860 and 1882, and also Halley (1910). C. P. B.

469. *Ionisation of Atmosphere by Halley's Comet.* **A. Wigand.** (Phys. Zeits. 18. pp. 1–6, Jan. 1, 1917.)—A summary is given of the observations of ionisation of the earth's atmosphere made at various stations in different countries during the presence of Halley's Comet in 1910. [See also Abs. 1211 (1910).] C. P. B.

470. *Determination of Star Colours.* **F. H. Seares.** (Nat. Acad. Sci., Proc. 3. p. 29, 1917. Nature, 99. p. 16, March 1, 1917. Abstract.)—A method of determining colour-indices of stars has been developed, involving the making of a series of exposures with graduated durations, first through a yellow filter and then without the filter. This gives data for obtaining the

ratio of exposure times necessary to give images of the same size in yellow and blue light. The colour indices are then obtained by comparison with similar ratios for standard polar stars. [See Abs. 309 (1916).] C. P. B.

471. *Classification of Helium Stars.* **A. Fowler.** (Nature, 99. pp. 25–27, March 8, 1917.)—Two main systems of classification of stellar spectra have been developed during past years, one regarding stellar evolution as being a continuous cooling from the white to the red stars, and constituting the basis of the systems of Rutherford, Secchi, Vogel, and the Harvard or Draper Catalogue; the second view is due to Lockyer, who considers the necessity of stars of increasing as well as decreasing temperature, so that for any one temperature apart from the maximum there may be stars of two types. From laboratory experiments the differences in spectra at these corresponding stages of equal temperature are ascribed to differences of physical and chemical structure of the stellar atmospheres. A review is given of an investigation by B. P. Herassimovitch [Acad. Sci. Petrograd, Bull., p. 1419, 1916] of the helium stars with respect to spectrum type, radial velocity, magnitude, and parallax. The K term is found to be very different for the stars on the two sides of Lockyer's curve, and it can no longer be assumed as a constant error. C. P. B.

472. *Distribution of Brighter A Stars.* **C. A. Maney.** (Astron. J. 30. pp. 19–20, Oct. 2, 1916.)—A discussion of the radial velocities of 401 stars of spectrum type A indicates that there is a relative motion of several km./sec. between the A stars of high and low galactic latitudes. Tables are given showing this and the distribution of the stars with respect to the Galaxy. C. P. B.

473. *Two New Variable Stars.* **B. H. Dawson.** (Astron. J. 30. p. 84, Jan. 24, 1917.)—A star near ζ Centauri, noted by Herschel as curiously triple, is found to have three companions, two of which are established as variable, although the data are not sufficient to determine the period or spectral type. C. P. B.

474. *New Variable Star.* **E. E. Barnard.** (Astron. J. 30. p. 4, Oct. 2, 1916.)—A new variable star has been found on the Bruce plates taken at the Yerkes Observatory, in the position $\alpha = 15\text{h. } 9\text{m. } 37\text{s.}$; $\delta = -5^\circ\ 12'$ (1855·0). It has been found on a number of the Harvard plates, with a variation of somewhat less than one magnitude. Visually it is about 13 or 13·5 mag. with period of about 7·1 days, and is possibly of the β Lyræ type. C. P. B.

475. *Pairs of Stars for Micrometer Screw Tests.* **A. Hall.** (Astron. J. 30. pp. 31–32, Oct. 24, 1916.)—Attention is drawn to standard measures of certain pairs of stars which have been employed at the U.S. Naval Observatory for the determination of the values of screws of equatorial micrometers, and it is requested that unpublished observations of the stars at other institutions may be printed. C. P. B.

476. *Parallax of Barnard's Large-proper-motion Star.* **H. N. Russell.** (Astron. J. 30. pp. 73–75, Jan. 8, 1917.)—Observations extending over five months indicate that the interesting large-proper-motion star discovered by Barnard has a very large parallax; the provisional value given is $\pi = 0{\cdot}70''$, which makes it nearer to us than any other known star except α Centauri. **F. Schlesinger.** (Ibid. pp. 75–77, Jan. 8, 1917.)—From measures on plates taken with the Thaw refractor at Allegheny and others taken at Harvard the

proper motion of this interesting star in Ophiuchus is found to be: in R.A. — 0·74″; in Decl. — 0·25″; its parallax is 0·50″. C. P. B.

477. *Parallax of Planetary Nebula N.G.C.* 7662. **A. van Maanen.** (Nat. Acad. Sci., Proc. 3. pp. 133–136, Feb., 1917. Nature, 99. p. 153, April 19, 1917. Abstract.)—Photographs of six nebulæ have been taken with the 60-in. reflector at Mount Wilson specially for determinations of parallax. The planetary nebula N.G.C. 7662 gives good measurable images with 25 minutes' exposure, showing a sharp stellar nucleus, and 16 plates of this object were secured between 1915 Nov. 2 and 1916 Nov. 17. The resulting absolute parallax is given as $\pi = +0{\cdot}023''$, corresponding to a distance of 140 light-years. As the angular diam. of the nebula is about 26″, its linear diam. would thus be of the order of 19 times that of the orbit of Neptune. C. P. B.

478. *Variable Nebula N.G.C.* 2261. **V. M. Slipher.** (Nature, 99. p. 54, March 15, 1917.)—This nebula, known as Hubble's variable nebula, is of cometic form, and has the irregular variable star *R* Monocerotis as its nucleus. Photographs of its spectrum have been obtained at the Lowell Observatory, showing that the nebula and star have the same spectrum, consisting of a continuous band, with bright lines not identical with those of gaseous nebulæ. Photographs taken by Lampland with the 40-in. reflector show striking differences in detail of the nebulous mass. C. P. B.

479. *Orbital Elements of Double Star ζ Boötis.* **Hertzsprung.** (Astron. Nachr., No. 4871. Observatory, No. 511. pp. 138–139, March, 1917.)—This star is especially interesting from the fact of its orbit having extremely high eccentricity, 0·96, and a period of 130 years. Some difficulty is experienced in the observations owing to the components being of the same brightness, as it then becomes uncertain as to the recognition of the components when they separate after being in conjunction, as they were in 1898. C. P. B.

480. *Axes of Symmetry in Globular Clusters.* **F. G. Pease** and **H. Shapley.** (Nat. Acad. Sci., Proc. 3. pp. 96–101, Feb., 1917.)—Counts of photographs of various globular clusters have shown that the stars are in general grouped along certain axes of symmetry, suggesting an elliptical formation. Special details are given for the cluster in Hercules, M13, and curves illustrating the results for other clusters are also analysed. C. P. B.

481. *Variable Stars in Clusters.* **S. I. Bailey.** (Harvard Circular, No. 193. Nature, 98. p. 455, Feb. 8, 1917. Abstract.)—Eight stars whose light-curves exhibit peculiarities have been found in the cluster M5. The mean period of 61 variables of the cluster type is 0·547 day, whereas that of these eight stars is only 0·271 day. Analysis of the light-curves suggests that such stars may be formed of two variables of the normal type. C. P. B.

482. *Motion in Spiral Nebulæ M.* 101 *and N.G.C.* 4594. **J. H. Reynolds.** (Observatory, No. 511. pp. 131–132, March, 1917.)—Attention is drawn to the difference of type of these two nebulæ; M 101 being of the granular type with nebulous condensations along the arms which are fairly well defined; NGC 4594 is of the structureless cloudy type, with its plane almost in the line of sight and the usual dark absorption band lying across the major axis. In M 101 the average proper motion in the nebula is con-

siderably larger than the average proper motion of faint stars in the field. Attention is drawn to the difficulties attending the determination of radial velocities of such faint objects with spectrographs of very small dispersion. C. P. B.

483. *Effect of Viscosity in Gases and Nebulæ.* **J. H. Jeans.** (Roy. Astron. Soc., M.N. 77. pp. 200–204, Jan., 1917.)—The author shows that viscosity (possibly of a somewhat generalised kind) can be highly effective in influencing the paths of matter in nebulæ, and that the paths, if determined by viscosity alone, would be equiangular spirals. G. W. DE T.

484. *Summary of Results of the Aurora Borealis Expedition of* 1913 *to Bossekop, Norway.* **C. Störmer.** (Terrest. Magn. 21. pp. 157–168, Dec., 1916.)—Determinations were made of the positions of 2500 points on the auroræ. The heights of these points are shown on a diagram and the distribution with regard to height is shown also by means of a curve. The lowest altitude observed was 87 km.; the curve rises steeply to a maximum number of points at about the 100 to 110-km. level and then falls gradually to a low value at 150 km., above which the records are few in number. It is considered that there are indications of two predominant maxima, at 101–103 km. and at 105–108 km. The minimum height of 87 km. for the 1913 aurora was higher than normal, and as frequency of solar activity and magnetic storms was at a minimum in this year it is probable that this high lower limit was due to the small penetrating power of the electric corpuscles emitted from the sun. In years of max. frequency of solar activity it has been found that the lower limit of the auroral displays is much nearer the earth. A map is reproduced which shows the geographical distribution of the points on the earth's surface vertically below the auroral points. These lie mainly to the west, north, and east of Bossekop. During years of max. frequency of aurora the displays are seen more to the south. The paper concludes with a discussion of the different types of aurora, and it is found that the lower limit does not lie at the same height in the different types so that these are probably associated with rays of different penetrating power. [See Abs. 1118 (1916).] J. S. Di.

485. *Height of Aurora Borealis observed at Haldde Observatory, Norway.* **L. Vegard** and **O. Krogness.** (Terrest. Magn. 21. pp. 169–174, Dec., 1916. Comptes Rendus, 163. pp. 442–446, Oct. 23, 1916.)—The work was carried out in the years 1913–14. The paper gives a summary of the more important results; a detailed discussion will be published later. 2487 determinations of height have been made from 415 pairs of successful photographs taken at the ends of a base line. Special attention has been paid to the bottom edge of the curtains. The auroræ have been separated into six distinct types, but unlike Störmer [see preceding Abs.] the authors conclude that a difference of form of the aurora is not necessarily associated with a difference in the type of the cosmic rays. The upper limit of the aurora was found to vary from about 100 km. to 330 km., but the top was often very faint and did not show up well on the photographic plate, so that the true upper limit may have been higher than these figures indicate. The average height of the bottom edge was 108·2 km. The distribution of this bottom edge with regard to height shows two very clearly marked points of max. frequency at 100 and 106 km. respectively. It is concluded that the aurora-producing rays which come from the sun may for the most part be placed in one or other of two groups each of which has its own penetrating power. J. S. Di.

LIGHT.

486. *Reflection at Surface of Separation of Two Fluids at Rest or in Motion.* **E. Esclangon.** (Comptes Rendus, 164. pp. 99–101, Jan. 8, and pp. 175–177, Jan. 22, 1917.)—In the first of these papers it is shown mathematically that the existence of a relative velocity at the surface of separation of two fluids (even though identical with one another) gives rise to both reflection and refraction of the incident wave. In the case of isolated waves the succession of phenomena in the refracted wave is the same as in the incident wave, but in the reflected wave the succession is reversed. The second paper deals with the total reflection of such isolated waves at the surface of separation.

A. W.

487. *Equation of Horizontal Rainbows.* **K. Otobe.** (Math. Phys. Soc., Tōkyō, Proc. 9. pp. 63–67, March, 1917.)—If the source of light is not at an infinite distance the horizontal rainbow will not in general be a conic section. The equation to the curve is here worked out and certain special cases are considered. From actual measurements made on one of these bows the angle θ between the incident ray and the refracted ray is worked out and found to be very nearly equal to that given by the exact theory of Airy.

J. S. Di.

488. *Focometry of Lens Combinations.* **R. E. Baynes.** (Phil. Mag. 33. pp. 357–358, April, 1917.)—A critical examination of the exactness of the method described by J. Anderson [Abs. 215 (1917)] for finding the focal length of a combination. The author shows that the data given in the original paper for a particular case lead to discordant results when treated in different ways.

J. W. T. W.

489. *Light Filters for Eye Protection.* **L. C. Martin.** (Engineering, 103. p. 373, April 29, 1917. Paper read before the Optical Soc., April, 1917.)—In a filter for reducing glare the reduction of actual luminosity of transmitted light is of first importance. Absorption of ultra-violet and infra-red is a desirable precaution under ordinary circumstances, but of the highest importance under certain special conditions. The glass of the optical system of a prism binocular absorbs half the possibly harmful ultra-violet rays. Molten glass at 1400° C. has max. energy at wave-length $1{\cdot}75\,\mu$; a Nernst glower at 2200° C. has a maximum about $1{\cdot}2\,\mu$. In general the tendency of metallic colouring oxides is to bring the ultra-violet limit of transmission for glasses nearer the visible region. Some "neutral" glasses are exceptions, though the intensity of the ultra-violet may be lowered. Glasses containing chromium have a slight absorption band near $0{\cdot}65\,\mu$. Copper and ferrous iron both give heavy absorption near $1\,\mu$, and so do cobalt and ferric iron when present together. Most of the other glass filters examined transmit well in the infra-red; in general the effect of the colouring material seems to diminish with increasing wave-length, and to become indistinguishable at about $4{\cdot}0\,\mu$. Dyed celluloids appear to have an ultra-violet limit of transmission at $0{\cdot}29\,\mu$. In the infra-red the dyes cause little absorption after $1{\cdot}0\,\mu$, but a band at $3{\cdot}0\,\mu$ is shown, which is probably due to the celluloid. Such a band is exhibited by many compounds containing O and H. Metallic films of Au, Ag, Pt are suggested as useful light filters, on account of their efficiency in reflecting the infra-red.

A. E.

490. *Effect of Small Amounts of Impurities, in particular Chlorides and Sulphates, in producing Turbidity or Opacity in Glass.* **W. E. S. Turner** and **J. D. Cauwood.** (Chem. News, 115. p. 154, March 30, 1917. Paper read before the Soc. of Glass Technology, March, 1917.)—Trouble has been experienced by manufacturers when using Russian potash as one of the components of a lead batch. The glass made with Russian potash, though found at first to be quite clear, gradually becomes milky as it stands at a lower temperature in the pot, or if after the glass has been worked, articles in course of formation are reheated. Analysis has shown that the only impurities present to any extent in Russian potash are phosphate, chloride, and sulphate. Phosphate is practically inactive in causing opacity, at least up to 1 % of the batch mixture, but chloride and sulphate do cause opacity, especially sulphate. Potassium sulphate, even so little as ¼ % of the batch, causes opacity when melting at 1300° is carried out until the glass is clear, followed by several hours heating at 950°–1000°. Chloride, to give opacity under the same conditions, must be present to an amount over ½ % of the batch. The best means of preventing the opacity is to employ high temperature, by which sulphate is decomposed, and chloride is volatilised. The results emphasise the need of more efficient furnaces, capable of reaching a high temperature, especially when dealing with the new types of glassware that now have to be produced in Britain. Attempts have been made to remove the milky appearance by addition of borax, but, as was pointed out in the discussion following the paper, borax fails to prevent the reappearance of milkiness when the glass is reheated. A. E.

491. *Motion-pictures in Colours and Relief.* (Scientific American, 116. pp. 263 and 269–270, March 10, 1917.)—A brief *résumé* of the subject is given.

The latest development in the production of colour motion-pictures, reproduces objects at rest and in motion, and in all the shades and colours found in nature, in addition to all of the detail present in the customary black-and-white pictures. There is a complete absence of the objectionable colour fringe found in some of the earlier processes when fast-moving objects were portrayed. It has also the still greater advantages of simplicity and wide applicability. The new film can be projected with any standard projector, after equipping it with a simple and inexpensive attachment which in no way interferes with the handling of black-and-white film. Four colours, made up of two pairs of complementary colours, are involved in the new process. The first pair is composed of red and blue-green, and the second of orange (or yellow) and blue. These four shades photographically cover the entire range of visible colours. The reduction to a substantial white from each pair of images and the fact that all colours overlap, enable the pictures to be made with but little apparent differences in densities, and this feature is further brought about by the addition of other elements in the making of the film. In the taking of the new pictures the camera controls a single strip of panchromatic film of standard width and perforation, this being pulled down step by step in back of a single lens, as in usual practice.

Between the film and the lens, however, two shutters are employed, the usual one to cover the film during the period when the film is moving, and another to bring into position the colour-filters through which the light rays must pass before reaching the film during exposure. A diagram is given showing the method of arrangement of the colour-filters of the camera, and full details are given as to the method of taking photographs and reproducing the original by means of a colour wheel geared to the projector, as shown in

two accompanying illustrations. The attachment for converting the standard projector into a colour-picture projector is also described. A. E. G.

492. *Photo-inversion.* **H. Saegusa.** (Math. Phys. Soc., Tōkyō, Proc. 9. pp. 56–63, March, 1917.)—It has been found that the photographs taken at the top of a volcanic cone showed positive pictures instead of negatives, and other photographs taken in the vicinity of the volcano were somewhat different from ordinary negatives, that is, they showed a thick line on the contours of the mountain, of trees, and of their shadows on the surface of water. It was thought at first that the above changes might be attributed to some radio-active substances in the volcanic region. On testing it was found that the lava gave out no radio-active rays. Photographs taken at sulphurous hot-springs show similar changes on the photographic plates. From these facts, it was suggested that a gas such as sulphur dioxide, which is often present in the atmosphere in volcanic regions, might have a certain action on the gelatine silver-bromide of the sensitive film and might cause the reversal. In this view the following experiments were carried out, the result of which shows that the photographic films of gelatine silver-bromide give rise to photo-inversion by the action of SO_2 gas, and may have positive or negative pictures if the concentration of SO_2 gas, the time duration to the exposure to the gas, and the intensity of the incident light satisfy suitable conditions. The concentration of SO_2 gas being constant, the degrees of inversion are different for different times of exposure. The time of exposure being constant, the degrees of inversion are different for different concentrations of SO_2 gas. A positive picture generally appears in a wider range of the intensity of light and of the time of exposure to SO_2 gas, for the weaker concentration of the gas than for the stronger. There exists for photo-inversion the commutative action between the exposures to the gas and to the light. The action of SO_2 gas gradually weakens with time and disappears generally within several hours. Photo-inversion closely resembles solarisation in the change of grains in the film. A. E. G.

493. *The Rotation Spectrum of Water-vapour.* **H. Rubens** and **G. Hettner.** (Deutsch. Phys. Gesell., Verh. 18. 5. pp. 154–167, 1916. Extract from Preuss. Akad. Wiss. p. 167, 1916.)—The authors re-examine the absorption spectrum of water-vapour with a view to the suggestion by Nernst and N. Bjerrum that not only the long waves (from about 9μ upward), but also those of shorter wave-lengths would show bands caused by the rotation of the water molecules in accordance with the quantum theory. Water-vapour is particularly suited for this investigation owing to the low moment of inertia of its molecules; even at ordinary temperature absorption bands become visible in the laboratory air about $\lambda = 10\mu$, and these absorptions disturbed the experiments. The energy measurements were made with tubes 104 or 32 cm. in length, charged with steam at 100° and heated by coils to 125°, with prisms of fluorspar (for short waves), rock-salt, sylvine, and gratings (silver wires, 0·1858 mm. in diam.) for the longest waves; the range investigated was 7 to 30μ; former experiments had been extended to several hundred μ. The results were compared with those of Eva v. Bahr, Eucken, and of Langley (solar spectrum lines ascribed to atmospheric vapour). The measurements confirm Bjerrum's calculations: the maxima are, however, not sharp, the bands being sometimes broad and indistinct, but they become sharper at lower vapour pressures. It would appear that the two hydrogen atoms are not equidistant from the oxygen atom in the water molecule; but this question requires further study. **M. Planck.** (Ibid. 168–172, 1916.)—

Planck accepts the main conclusion of Rubens. If the water molecule describe ν rotations per sec., the max. absorption bands should have the distance $(\nu_{n+1} - \nu_n)$, and this difference would represent the increase in the rotation frequency connected with the transition of the energy of rotation (per molecule) from a quantum value of the order n to that of $(n + 1)$. The measurements are important because the rotations (as distinct from the oscillations of atoms) constitute free movements of well-defined systems, *i.e.* rigid or approximately rigid dipoles; to these movements the law of electrodynamics are applicable. But the phenomena are much more complex because the value of ν changes with the absorption, when radiant energy is converted into rotational energy, so that to a particular line of the absorption spectrum there corresponds, not a definite, but an ever-changing molecular individuality. The separate molecules may be imagined to be coordinated, according to their momentary ν, to the different parts of the spectrum, and to wander in the spectrum, jumping from one particular point n, to the next n_1. It must not be supposed that owing to the heat radiation every molecule will continuously undergo an acceleration of its rotation; there will also be retardation [see Fokker, Abs. No. 1087 (1914)] in agreement with classical electrodynamics. To overcome difficulties the author suggests that the molecule, when in suitable condition for emission, *i.e.* for giving up its energy of movement, will also be fitted for dispersing the energy of the incident radiation. H. B.

494. *Reduction Formula for Prismatic Spectra.* **M. Hamy.** (Comptes Rendus, 163. pp. 463–465, Oct. 30, 1916.)—It has previously been shown [Abs. 1035 (1915)] that the formula—

$$\lambda - \lambda_0 = (l - l_0)/[A_0 + A_1(l - l_0) + A_2(l - l_0)^2 + \ldots + A_n(l - l_0)^n]$$

can be used to calculate the wave-lengths of the lines recorded on a prismatic spectrogram, A_0, A_1, ... A_n being constants and $(l - l_0)$ the distance, measured on the plate, of any line of wave-length λ from the line of wave-length λ_0 chosen as origin. The constants A are determined by observations on $(n + 1)$ lines other than the line selected for origin. $(n + 1)$ linear equations are thus obtained which can be solved quickly by combining them to obtain a new system in which the first has $(n + 1)$ unknowns, the second n, the third $(n - 1)$, and so on. A result is thus obtained, in general, much more quickly than by applying Cramer's formulæ. Further details of the method are given, and it appears that usually it is quite sufficient to retain not more than three terms in the denominator. A. W.

495. *Grouping of Lines in Spectrum of Iron.* **G. A. Hemsalech.** (Comptes Rendus, 163. pp. 757–759, Dec. 11, 1917.)—Gives a short account of research on the selective effect of thermal and chemical action, from which it is shown that certain lines in the spectrum of iron can be grouped together. The matter has previously been dealt with [Abs. 222 (1917)]. **A. de Gramont.** (Ibid. pp. 759–760, Dec. 11, 1916.)—de Gramont calls attention to the importance of the results obtained by Hemsalech. He points out that the lines of great sensibility, which he had previously discovered, belong to classes I and II of Hemsalech's groups, and are triplets converging towards the red. Class III, whose triplets converge towards the violet, and which comprises the lines of highest temperature, appears to correspond to Lockyer's enhanced lines, or at any rate to include these among them. A. W.

496. *The Lower Energy Limit for Light Emission by Collision.* **J. Stark.** (Deutsch. Phys. Gesell., Verh. 18. 2/3. pp. 43–51, 1916.)—The author had in 1907 made use of the quantum theory to explain the fact that the emission of a line in the spectrum can only be excited by collision when the kinetic energy of the striking particle exceeds a minimum limit (Schwellenwert). Reconsidering the problem he concludes that the phenomena can be explained without having recourse to the quantum hypothesis. He discusses two cases: (1) The carrier of the line-vibrations must first be created by ionisation. It is generally admitted, probably, that to separate a single neutral atom (from a molecule of several atoms) or a positive atom-ion (from its negative electron) by collision with a particle of kathode or canal rays, this particle must possess a certain energy. But this separation may be accompanied or succeeded by some other phenomenon; the dissociated atom or atom-ion may be excited, during or after the collision, to vibrations in the interior of the atom and thus to light emission. In that case the lower energy limit would not be characteristic for the light excitation; but the two phenomena, dissociation and light emission, would only be connected by the intermediation of the common carrier. There must first be dissociation, necessitating a certain amount of work; that is the significance of the energy limit. The researches of the author, Gehrcke and Seeliger, and others, show that the light emission in various gases becomes very feeble when the velocities of the kathode or canal rays are lowered, and the fluorescence of salts seems to depend on similar conditions. But it does not follow that the product of efficiency and kinetic energy must be equal to or greater than the light-quantum. The intensity minimum in the canal-ray Doppler-effect is particularly discussed with respect to the series lines of hydrogen in connection with the work of W. Wien, J. Königsberger, and J. Kutschewski. The free path of a canal-ray particle between two consecutive changes of ionisation and neutralisation, it appears, is merely of the order of the mean free path of a gas particle, amounting for hydrogen to 0·05 to 0·5 cm., for dark spaces (in which the canal rays are accelerated) from 15 to 3 cm.; the possible number of changes is hence very great. But the change, neutral to positive, can only take place when the kinetic energy of the particle exceeds that of the ionisation potential; when the energy falls below the limit, the particle remains neutral and acceleration is no longer possible.

(2) The second case considered is that the colliding particle (slow kathode ray) is only created in numbers sufficient for visible light emission when the ionisation potential is exceeded. "So soon as the kinetic energy of an electron attains the value $h\nu$, this energy quantum is, in one of the subsequent collisions, transferred to the spectrum in the atom, of frequency ν" (Franck and Hertz). The mercury-arc line 2536 first becomes visible at 4·9 volts, when no other line is visible. The author objects that this is a question of relative intensity. At high vapour pressure that line is weak owing to absorption in the vapour outside the current path; at low pressure this line (from the positive column) greatly exceeds all the other ultra-violet lines in intensity (more than 100 times); therefore λ2536 appears under conditions, in which the others are invisible. The carrier of this line might be the positive atom-ion or the neutral Hg-atom; it is strange that the energy minimum should be the same for emission from the neutral atom and for ionisation. H. B.

497. *Generation of Light by Canal Rays.* **L. Vegard.** (Ann. d. Physik, 52. 1. pp. 72–100, Feb. 15, 1917.)—A criticism of the results obtained by Hirsch. The conclusion is arrived at that Hirsch did not measure the

intensity, but his results only gave direct photometric curves from which it is difficult to draw any certain conclusions. A more definite comparison between lines of different blackening or of different plates is not possible. In so far as conclusions can be drawn from his curves, it shows that none of Hirsch's observations are in disagreement with the "displacement effect" by canal-ray excitation, as demonstrated by the author, but rather that through this effect they can in some measure be explained. The experimental arrangement employed by Hirsch did not allow of a variation of pressure with constant ray-velocity, and it is shown that he has not been able to prove a pressure effect. The existence of pressure and velocity effects is a necessary consequence of the condition, that a ray can give out only a known quantity of energy per unit of time. The earlier researches of the author point to the conclusion that neutral rays emit light. The generation of light can take place without ionisation also occurring. The intensity distribution in the H-spectrum generated by canal rays, as also the variation which subdues it, get a satisfactory explanation by the assumption of a "number of collision effects" in which the ratio H_α/H_β increases with increasing number of collisions per unit of time, first very slowly and then more quickly. The "number of collision effects" is in agreement with Bohr's theory. The colour displacement of the "moving" intensity shown by the author supports the relationship established by Stark that the intensity distribution of the "rest" spectrum alters with the distance from the canal-ray layer. An explanation of the colour displacement in the negative glow light is based on the alteration of the average velocity of the light-generating canal rays.

A. E. G.

498. *Periodic System of Elements in Spectral Analysis.* **V. Kutter.** (Phys. Zeits. 18. p. 67, Feb. 1, 1917.)—A diagram is here given to replace that in the original paper [see Abs. 391 (1917)]. A. W.

499. *Mutual Repulsion of Spectrum Lines and Anomalous Dispersion.* **J. Larmor.** (Astrophys. J. 44. pp. 265–272, Dec., 1916.)—Various details of the possible effects of anomalous dispersion are discussed, with special reference to the visibility of solar phenomena and the different views as to mutual repulsion of spectrum lines of different intensity and position.

C. P. B.

500. *Mutual Influence of Fraunhofer Lines.* **C. E. St. John.** (Mt. Wilson Solar Observatory, Contrib. No. 123. Astrophys. J. 44. pp. 311–341, Dec., 1916.)—A long analysis is given of various groups of solar and arc spectrum lines, free and with close companions, with the result that no evidence whatever is found favouring the idea of mutual influence of spectrum lines. In the case of certain lines with close companions the displacements noted by Albrecht correspond so closely with the recently detected errors in the Rowland wave-lengths that they are most satisfactorily explained by this means. It is concluded that the observational evidence is against the possibility of anomalous dispersion being the cause of any important solar phenomena [Abs. 19 (1915); 536 (1916)]. C. P. B.

501. *Triboluminescence.* **A. Imhof.** (Phys. Zeits. 18. pp. 78–91, Feb. 15, 1917.)—The research here dealt with is a contribution to the knowledge of triboluminescence in general. The results may be summarised as follows:—(1) For each substance there is a specific minimum crystal size, for which it may just be brought to luminescence. This size is the smaller the greater

the brightness of luminescence, and lies between the approximate limits 0·002 and 4 mm. diam. (2) The intensity of triboluminescence is a function of the temperature of the substance, in the sense that the brightness at higher temperatures is smaller than at lower, but the curve at a certain low temperature falls again. The changes in brightness for different substances are of altogether different magnitudes. Temperatures were employed varying from a red glow to −80° C. (3) Triboluminescence with phosphorescent substances is hardly affected by temperature, and can therefore be observed if the phosphorescence approximately vanishes on heating the substance. (4) About 90 inorganic substances were tested, and 25 % of these were found to be triboluminescent. A number of minerals and amorphous substances were also dealt with. (5) Almost all inorganic double salts, which are sulphates of potassium or ammonium (probably also of the other alkali metals) and some other metal are triboluminescent, and all those which are chlorides of these metals are not triboluminescent. (6) In general the rule holds that chemically similar inorganic salts behave in the same way as regards triboluminescence. A number of such groups have been obtained. (7) The elements themselves are probably not triboluminescent. (8) Salts of similar general chemical composition, but with different amounts of water of crystallisation behave like altogether different substances with respect to triboluminescence. Almost invariably the highest hydrate is triboluminescent, but other cases also occur. (9) Triboluminescence is not confined to crystal substances, but is shown also by a small number of amorphous substances which also exist in crystal form. (10) A table is given of 88 substances with the corresponding triboluminescence colour. In about 47 % the colour is blue ; in 25 % yellow or orange ; it is seldom violet and very seldom red or white ; red is only found with minerals. (11) The colour of triboluminescence is dependent on the temperature to a certain extent.

A list is given of recent papers on the subject. A. W.

502. *The Primary High-frequency Spectra of Iodine and Tellurium.* **M. Siegbahn.** (Deutsch. Phys. Gesell., Verh. 18. 1. pp. 39–40, 1916.)—Experimenting with zinc compounds of the two elements by the secondary radiation method, M. de Broglie [see Abs. 1838 (1914)] concluded that the order of the atomic numbers should be Te-I, as chemically to be expected. Using the pure elements, I. Malmer by the same method (Lund Dissertation, 1915) found the order I-Te. The author uses the element's primary radiation, a silver antikathode, and a rotating rock-salt crystal, and finds the wavelengths of two lines $\alpha_1 = 0{\cdot}437 \times 10^{-8}$ cm. for I and 0·456 for Te, and $\beta_1 = 0{\cdot}388$ for I and 0·404 for Te. These values fall in with those of other elements ; the order is therefore tellurium-iodine. [There seems to be some confusion in these statements as to the order of the two elements as well as in the diagram in which $\sqrt{1/\lambda}$ is plotted against the N, the atomic number.] H. B.

503. *New l-Series in High-frequency Spectra.* **M. Siegbahn.** (Deutsch. Phys. Gesell., Verh. 18. 5. pp. 150–153, 1916.)—In his search for characteristic rays of greater wave-length outside the L-series the author first investigated the range $\lambda 1{\cdot}15$ to $2{\cdot}30 \times 10^{-8}$ cm. of the bismuth X-ray spectrum. He found only one line of sufficient intensity, although the weak L lines were clearly visible. He assigns this new line (2° outside the Lα line) to the new *l*-series (closely allied to the L-series), and he observed similar lines subsequently for W, Ir, Pt, Au, Tl, Pb, Bi, Th, U, but not in all the metals of high atomic weights. He failed to discover any traces of Laub's J-series. H. B.

504. *Results of Crystal Analysis.* III. **L. Vegard.** (Phil. Mag. 32. pp. 505–518, Nov., 1916.)—This paper gives an account of the determination of the structure of the two crystals xenotime (YPO_4) and anatase (TiO_2), both of which belong to the ditetragonal bipyramidal class of the tetragonal system [see also Abs. 155, 1041 (1916)]. The lattice of xenotime differs from that of zircon in the arrangement of the O-atoms. In xenotime, the O-atoms are arranged in groups of four round each P-atom, while in zircon both Zr and Si have essentially the same relation to the O-atoms. The lattice gives the constitution formulæ Y (PO_4) and ZrO_2 SiO_2 for xenotime and zircon respectively. But in spite of the different arrangement of the O-atoms which accounts for the chemical differences, the lattice also accounts for crystallographic similarity of the two substances. Both possess the right symmetry, and in both cases the same relative number of O-atoms are arranged in planes perpendicular to the tetragonal axis, and will expand the lattice perpendicular to this axis to the same extent and make the ratio c/a smaller than unity and almost equal for both crystals.

The lattice of anatase can be derived from the zircon lattice by removing the Zr-atoms and the O-atoms associated with them, and substituting Ti-atoms for the Si-atoms. The O-atoms seem no longer to be able to remain in the position they had in zircon; the molecular axes all turn through an angle of 90° so as to become parallel to the tetragonal axis, and so form the stable lattice of anatase. The deformation of the lattice from the cubic form, in the case of anatase, is also due to the O-atoms. The molecular axes being all parallel, the lattice expands most in the direction of the tetragonal axis to make room for the O-atoms, and thus make the ratio c/a greater than unity.

The absolute dimensions of the lattices are given in the following table. For the sake of comparison the dimensions of lattices of the zircon group are also given.

Substance.	a.	c.	c/a.	V.	l.
	10^{-8} cm.	10^{-8} cm.		10^{-22} cm.^{3}.	10^{-8} cm.
ZrO_2 SiO_2	9·20	5·87	0·639	4·97	(Zr) 2·71 (Si) 1·08
$S(SnO_3)_2$	9·35	6·29	0·673	5·50	2·08
$(TiO_2)_2$ (Rutile)	9·05	5·83	0·644	4·77	1·99
TiO_2 (Anatase)	5·27	9·37	1·777	2·60	1·95
YPO_4 (Xenotime) ...	9·60	5·94	0·618	5·49	1·23

V is the volume of the elementary lattice, l is the distance from an oxygen atom to the central atom to which it belongs. E. A. O.

505. *X-ray Emissivity as a Function of Kathode Potential.* **D. L. Webster.** (Phys. Rev. 9. pp. 220–225, March, 1917.)—The theoretical deductions included in this paper are summarised as follows:—(1) That if radiation occurs in quanta, the probability of its occurrence with any one frequency in any one atom struck by a kathode electron rises from zero to a finite value when the energy of the kathode electron is increased past the quantum. (2) That for the case of rhodium at least, the probability decreases with any further increase of energy of the kathode electron. (3) That these laws of quantum collisions are radically different from those of collisions which merely slow down the electron slightly without producing X-rays. A. B. W.

506. *Absorption Coefficients of High-frequency X-rays.* **S. J. Allen** and **L. M. Alexander.** (Phys. Rev. 9. pp. 198–204, March, 1917.)—The work of Rutherford and Barnes on the absorption of "hard" X-rays is criticised on the grounds that their measurements of the absorption coefficients of the "end rays" only represent a certain "average" and not the hardest components. Experiments are now described in which measurements have been made, at a voltage of 120,000, of the absorption coefficients of the X-rays from a Coolidge tube after filtering through various elements. These absorption coefficients show clearly the presence of the K-radiation of Pt, Au, Pb, and Bi. With a tin filter the values of the absorption coefficients for the "end-rays" show harder rays than any that have been published up to this time, the value of λ/ρ for Al being 0·12. Experiments show that scattering is most marked in the case of elements of low atomic weight. A. B. W.

507. *Intensities of X-rays of the L-Series.* **D. L. Webster** and **H. Clark.** (Nat. Acad. Sci., Proc. 3. pp. 181–185, March, 1917.)—This paper contains a brief report on a study of the intensities of X-rays, L-series, of platinum considered as functions of the potential producing them and in their relations to each other and to the general radiation. The results so far obtained indicate that the rhodium K series and the platinum L_1 and L_2 series all increase in intensity approximately in proportion to the 3/2 power of the difference between the potential applied to the tube and the "critical" potential of the series. From measurements of critical potentials and relative intensities of the L-radiation and general radiation, a value of Planck's constant $6{\cdot}53 \times 10^{-27}$ erg. sec. has been obtained—this being in good agreement with the value $6{\cdot}57 \times 10^{-27}$ erg. sec. found by Millikan in his experiments on photo-electrons. A. B. W.

508. *Penetrating Radiation in the Atmosphere.* **G. C. Simpson.** (Nature, 99. pp. 124–125, April 12, 1917.)—Experiments have demonstrated that the number of ions generated per cm.^{3} per sec. in a hermetically sealed metal box increases rapidly with increase of height above the ground. This effect commences at about 2 km. and is continued up to 9 km., the greatest height attained in the experiments. This can only be accounted for on the hypothesis of a far more penetrating radiation in the atmosphere than any previously known [see Abs. 1373 (1916)]. The source of this penetrating radiation has been the subject of speculation since its existence was established. E. v. Schweidler finds that if the radiation were sent out from the sun the latter would have to possess a specific activity 170 times as great as that of pure uranium, a most improbable value. An alternative explanation that cosmical space is filled with a radio-active gas of a specific activity 1/1200 that of uranium appears partially to account for the facts observed, though this explanation does not find favour with v. Schweidler.

Linke has suggested a layer of strongly radio-active cosmical dust in the atmosphere at a height of 20 km. and puts forward several arguments in favour of this hypothesis. More observations are, however, required before this suggestion can be fully tested. Simpson pleads that mathematical physicists should take account of this new penetrating radiation, the existence of which is clearly demonstrated. J. S. Di.

509. *Moseley's Law for X-ray Spectra.* **H. S. Uhler.** (Nat. Acad. Sci., Proc. 3. pp. 88–90, Feb., 1917.)—In making certain observations the author noted small systematic deviations from Moseley's law. This led to an investigation of the following questions: (1) How accurately does Moseley's law

reproduce the observed wave-lengths? (2) What empirical formula will represent the numerical data within limits of experimental error? and (3) What is the order of magnitude of the high-frequency radiations of elements having small atomic numbers and of which the spectra have not yet been obtained?

In answer to (1) the author considers that Moseley's law does not hold for the entire range of the L-series and that it seems to be slightly inexact for the most intense lines of the K-series. The empirical formula—

$$\sqrt{\nu_N} = A + BN + C(D + N)^{-1}$$

is proposed as a satisfactory answer to (2). A tentative answer is given to (3) as it involves extrapolation. A. B. W.

RADIO-ACTIVITY.

510. *Atomic Weight of Lead of Radio-active Origin.* **T. W. Richards** and **C. Wadsworth.** (Am. Chem. Soc., J. 38. pp. 2613–2622, Dec., 1916.)—Recent investigations upon the atomic weights of lead from radio-active materials have proved that the substance derived from this source has a much lower atomic weight than lead [see Abs. 1751 (1914)]. The present paper represents further research in this direction embodying the determinations of the atomic weights of new samples of varied origin. The outcome supports the earlier conclusion. The results are as follows:—

	Atomic Weight.
Ordinary lead	207·18
Radio-lead (Colorado)	207·00
Radio-lead (Australia)	206·34
Radio-lead (obtained from bröggerite from Norway)	206·12
Radio-lead (obtained from Langesund clevite, Norway)	206·08

That the most carefully selected sample should give the lowest result is strong evidence that the higher results obtained from other samples were due merely to accidental admixture of ordinary lead. An examination of the ultra-violet and visible spectra of the above types of lead revealed no lines other than those found in the case of ordinary lead. A. B. W.

511. *Thorium Lead.* **O. Hönigschmid.** (Phys. Zeits. 18. pp. 114–115, March 1, 1917. Paper read before the Deutsche Bunsen Gesell., Dec., 1916.)—Assuming ThE to be the final, non-active product of thorium and an isotope of lead, the atomic weight of ThE should be 208·1. As all thorium minerals contain uranium, however, the separation of the RaG (at. wt. 206) from the ThE would hardly be possible. From a study of thorite from Ceylon and density measurements Soddy [see Abs. 502 (1915)] deduced the at. wt. of thorite lead as 207·74. [The author gives this value instead of 207·64 as stated by Soddy, and 207·2 for lead; in 1914 the value 207·1 was still the internationally accepted value.] Using Soddy's original material, the author determined the atomic weight for thorium lead directly by distilling the chloride and determining the ratios $PbCl_2 : 2Ag$, and $PbCl_2 : 2AgCl$, after the method of T. W. Richards; the result, 207·77, agrees well with that of Soddy [see also Abs. 310 (1917)]. Lead from thorite poor in uranium seems certainly to have a higher atomic weight than common lead. From the periods of thorium and uranium the author further estimates that RaG and ThE should be present in thorite in the ratio 10 : 90; that estimate would lead to the atomic weight 207·9 for ThE. H. B.

HEAT.

512. *Homogeneity of Expansion of Invar.* **C. E. Guillaume.** (Comptes Rendus, 163. pp. 966–969, Dec. 26, 1916.)—Doubts arose in the author's mind as to whether the expansion of commercial articles made of invar, such as metre scales, pendulum rods, and geodetic tapes and wires, can be considered identical with that found on the comparator in the laboratory. Local differences in properties may be anticipated in specimens ; and even when metal is obtained from the same melting the divergence in action of two specimens might be of practical importance. To test this the author used in one case meltings from a crucible containing 300 kg. and in others from an oven holding 6000 kg. In this and other cases quoted the results obtained were sufficiently similar to indicate the practical identity of results provided the composition and treatment of the specimens is attained with the care hitherto used. P. E. S.

513. *Thermal Diffusion.* **S. Chapman** and **F. W. Dootson.** (Phil. Mag. 33. pp. 248–253, March, 1917.)—Chapman has shown mathematically [Abs. 147 (1917)] that a temperature gradient, maintained in an initially uniform mixture of two gases, will cause the heavier molecules to diffuse in the direction of diminishing temperature and the lighter ones in the opposite direction. The limit to the inequality of composition thus set up is reached when the effect of the thermal diffusion is balanced by the opposing process of ordinary diffusion. The existence of this phenomenon has been demonstrated with various mixtures of H_2 and CO_2, and of H_2 and SO_2. Two spherical bulbs (each 100 cm.^{3} capacity), connected by a short tube provided with a stopcock, contained the initially uniform gaseous mixture. One bulb was then maintained at 230° C. and the other at 10° C. After allowing time for a steady state to be reached the stopcock was closed and the mixtures analysed. In one experiment the heated bulb was found to contain 44·9 % H_2 and 55·1 % CO_2, the other 41·3 % H_2 and 58·7 % CO_2. Thus the diffusion takes place in the predicted direction. The theoretical magnitude of the effect depends on the molecular model used (it is zero for Maxwellian molecules). The experimental values are all within the possible limits. More exact quantitative experiments are in progress. D. O. W.

514. *Thermal Behaviour of Certain Compressed and Condensed Gases at Low Temperatures.* **A. Eucken.** (Deutsch. Phys. Gesell., Verh. 18. 1. pp. 4–17, 1916.)—The gases were condensed up to 36 mols. per litre, in a metal spiral and a calorimeter (steel bomb of 3·48 cm.^{3} capacity), part of the apparatus being placed on a balance. The gases were first hydrogen and helium, then argon, nitrogen, oxygen, CO, and CO_2. In some cases the determinations concerned the solid, liquid, and gaseous states, and the heats of liquefaction and vaporisation and of transformation, in addition to molecular and atomic heats and compressibility. The heat of fusion of argon is 267·9. Nitrogen was found to occur in two solid modifications, with a transition-point at 35·5° ; the melting-point was 63·1°, the molecular heat of fusion 168·7, the heat transformation 53·8. Oxygen was observed in three modifications (two according to Wahl) with transition temperatures at 23·5° and 42·5°, heat of fusion 105·5, and heats of transformation 17·5 and 167·4. Carbon monoxide was observed in two modifications ; transition temperature 60·4°, heat of fusion 224·1, heat of transformation, 144·1. The transitions, which were mostly rapid except in the case ofoxygen, hardly affected the specific heats at all. H. B.

515. *The Reduced Gas Constant $R = 3\frac{2}{3}$ and Heat of Vaporisation.* **L. Schames.** (Deutsch. Phys. Gesell., Verh. 18. 1. pp. 35–38, 1916.)—By a new method the author deduced (Elster-Geitel Festschrift, p. 287, 1915) a reduced gas constant $R = RT_x/mp_xv_x$, and this R has the same value, 3·42, for a number of various substances, such as oxygen, nitrogen, air, argon, ethylene, CO, methane, and probably simple hydrocarbons, whilst complex hydrocarbons—and also hydrogen and helium, which form a group of their own—do not belong to this group of constant R. The members of this group are characterised by the absence of opalescence (K. Onnes, Cardoso), and further (1) by the relation that $L_1/(d_2 - d_1)$ is constant for the whole range up to the critical temperature, where L_1 is the heat of vaporisation and d_2 and d_1 are the densities of the liquid and the saturated vapour; (2) by the ratio Density of the liquid/Density of the solid = Heat of vaporisation/Heat of sublimation.

The deduction furnishes a mathematical proof of Nernst's heat theorem. H. B.

516. *On the Equation of State of Solid Bodies.* **M. B. Weinstein.** (Ann. d. Physik, 52. 2. pp. 203–217, March 6, 1917.)—At the conclusion of a previous communication the author referred to the difficulty entailed by the thermal expansion coefficients of substances in connection with the chief equation of all former theories, viz., $\kappa J C_v = 1/\tau \cdot v/v_0 \cdot (\partial v/\partial\theta)_p$. Grüneisen has shown that Thiesen's formula, when applied to the total expansion of a large number of bodies, gives good results when the lower temperature limit is reduced to 83° abs., the data at the lower temperatures being better than those at the higher, while $\partial v/\partial\theta$ only attains about 1/10th of this formula value. Other observations are not unfavourable to Thiesen's formula, *e.g.* Valentiner and Wallot found that the temperature intervals should be much smaller than were regarded by previous investigators, so that the value of $\partial v/\partial\theta$ approaches more nearly the formula result. The values of $\partial^2 v/\partial\theta^2$, however, are so erratic that the Thiesen formula is insufficient, and must be supplemented. A research by Lindemann pointed to a similar conclusion, the temperature limit being taken as low as 20°, and the substances examined included Al, Cu, Mn, Ag, glass, quartz, rock crystal, and boric acid. The gradient of $\partial v/\partial\theta$ continually grows with falling temperature for these substances in consonance with Grüneisen's results for Pt, Pd, Cu, Ag, Fe, Ni, and Al. In some cases the gradient appears first to fall with lowering temperature and then to rise, for instance: Pt. Exceptions to the above behaviour are found in the cases of lead and the diamond, where the gradient of the expansion coefficient falls continuously as the temperature falls. Röntgen found that silicon had a max. density between 135° and 100°, *i.e.* long before 0°, and that $\partial v/\partial\theta$ changed its sign. A similar result was found for zinc and some other substances. The author next discusses an equation of state derived from his own propositions, namely: $(p + K)v = R\theta[V_1(1/\theta + \phi) + V_2(1/R\theta)E]$, where ϕ is a function of θ which when multiplied by θ remains finite, E is the energy whose differential with respect to θ gives the atomic heat, while V_1, V_2 are functions of v only. This equation receives detailed mathematical examination, and the author claims it to represent the behaviour of solid bodies. The extraordinary behaviour of the diamond is explained by some investigators as due to molecular aggregates, but the present author favours the view that the molecules are split up into Ur-atoms without, however, a complete dissolution of the union. This view is examined mathematically at some length. H. H. Ho.

517. *Zero-point Energy and Planck's Action Quantum* h. **K. Eisenmann.** (Deutsch. Phys. Gesell., Verh. 8. 6/7. pp. 170–180, 1916.)—The publication of Nernst's considerations [see Abs. 519 (1917)] induces the author to call attention to views previously expressed [Abs. 701 (1914)] and since developed, but not fully worked out. He deduces a formula for the connection between zero-point energy and potential energy, assuming that the atoms at absolute zero form a homogeneous medium R which only the addition of heat (energy quanta) will split into atoms, so that the solid body would contain this medium R, and further the medium A of the atoms, the total number of which, free and bound, would be N. The medium R consists of resonators, and at absolute zero the frequency ν_m has the same significance for R as that which the temperature T has for the medium A; thus h would be the entropy-constant (the potential energy) for the absolute zero (as k is for the kinetic energy). H. B.

518. *The Heat of Monatomic Fluids.* **A. Eucken.** (Deutsch. Phys. Gesell., Verh. 18. 1. pp. 18–26, 1916.)—It is to be expected that the specific heat will not undergo any principal change when a substance is heated at constant volume from its melting-point to temperature above the critical. There are two facts: (1) Near the melting-point the specific heats of the liquid and solid are nearly the same. (2) Immediately above the melting-point the specific heat first shows a negative temperature coefficient (H. T. Barnes, 1909) which becomes smaller as the temperature is raised and turns positive; this latter fact may be due to a temporary increase in the polymerisation, similar to that associated with the abnormal rise of the specific heat just below the melting-point. The thermal movements (c_v) of the solid and liquid are probably of similar nature. If then the thermal movement of the liquid be also vibratory in the first instance the formulæ of the quantum theory should be applicable as for solids. This is tested for liquid hydrogen, the limit c_v value (at high temperatures) of which is 6 cals. Below 60° abs. hydrogen behaves like a monatomic gas, and the values of c_v at 35°, 27°, and 20° were 3·6, 3·2, 2·8. The limit should be = 3 cals., and according to Keesom either of the two equations of Planck might be applied, the first assuming that there is no energy quantum at zero temperature, the second assuming that there is. The first assumption agrees better with the observations, and the author—supposing the limiting frequency to increase with rising temperature proportionally to $\sqrt{E}$ (energy), and not to be constant as Debye suggested—concludes therefore that there is no zero-point energy. H. B.

519. *Quantum-theoretical Considerations. Return to Steady Energy-changes.* **W. Nernst.** (Deutsch. Phys. Gesell., Verh. 18. 4. pp. 83–116, 1916.)—The attempt to return to steady energy changes is divided into four sections. (1) *General principles.*—The absolute zero cannot mean an end of all movements in view of magnetic and radio-active phenomena. Hence the need of Planck's zero-point energy which, however, involves difficult assumptions, *e.g.* that an electron circulating by virtue of this energy is not supposed to emit radiations. The author therefore suggests that space (the ether) is filled with radiation—even in the absence of any radiation excited above zero—of an energy density $= 8\pi\nu^3 . h\nu/c^3$ (where c = velocity of light). The zero-point energy is free energy; each degree of freedom of energy $kT/2$ (where $k = R/N$ according to statistical mechanics) corresponds to $h\nu/2$. When the temperature rises, the body does not only take up heat from outside, but transforms part of the zero-point energy into heat motion, and the variation

is in accordance with Rayleigh-Planck, $8\pi\nu^2 . kT/c^3$. The first law of thermodynamics becomes statistical in analogy to the second. (2) *Generalisation of the law of uniform energy partition.* (3) *Radiation, specific heat, vapour pressure, chemical equilibrium.*—The theory of the energy of rotation of rigid molecules and of the "degeneration of gases" (the fall of c_v below 3R/2 at very low temperatures) and the vapour-pressure curve can be explained; the considerations suggest a new model of the monatomic atom. (4) The new model of the hydrogen molecule has two circulating electrons; they receive from the zero-point radiations their orderly zero-point energy, which fluctuates little by comparison with the heat movement; this energy accounts for the great stability of the hydrogen molecule, but cannot give rise to radiations being in equilibrium with the zero-point radiation. At finite temperatures all potential energy may be traced back to zero-point energy and heat movements, and can be calculated by the aid of the heat theorem. The zero-point energy of a body of mass M is $Mc^2/2$. At low temperatures gas expansion, cohesion, chemical force, Newtonian force, radio-activity, etc., are identical phenomena, all due to the conversion of zero-point energy into work. Planck's constant h is characteristic of the ether, like the velocity of light. The question whether near absolute zero all potential energy consists of zero-point energy, and whether potential energy, and hence force, can be traced back to hidden movements, is discussed in an appendix; it was already raised by Hertz in his "Mechanics."

L. Zehnder. (Ibid. 6/7. pp. 181–183, 1916.)—The argument of Nernst that the ether is of atomic structure and that a material system, losing its zero-point energy, would attain its maximum possible velocity, that of light, which is characteristic for the ether, seems to imply that the atoms of the ether themselves possess that velocity and oscillate with it. Though Zehnder cannot understand Nernst's circular orbits of the ether atoms, these views would accord with his ideas concerning the author's atom model [see Abs. 462 (1917)] in which he considered the heat of the ether to be analogous to what is called electricity. H. B.

520. *The Nernst Theorem and the Thermal Expansion of Solid Bodies.* **M. B. Weinstein.** (Ann. d. Physik, 52. 2. pp. 218–220, March 6, 1917.)—From the author's previous work on the equation of state for solid bodies, he considers that Nernst's theorem is endangered as a fundamental law, if experimental data on the thermal expansion of solid bodies have to be so interpreted that the coefficient does not generally disappear at the absolute zero. Planck's explanation receives mathematical attention, viz., that all condensed bodies at the absolute zero possess equal entropy, and the conclusion is drawn that the Nernst theorem appears to be only an approximation law. Under these circumstances the expansion coefficient need not be nil at the absolute zero. The special case of silicon is quoted where the expansion coefficient is zero long before $\theta = 0$ and then changes sign. H. H. Ho.

521. *Determination of Free Energy by the Clausius Equation of State.* **E. Ariès.** (Comptes Rendus, 163. pp. 737–741, Dec. 11, 1916.)—For the molecular weight of a body the equation of state of Clausius may be written $p = RT/(\nu - \alpha) - \phi(T)/(\nu + \beta)^2$. If the latter of the constants α and β be zero, and if the function ϕ is reduced to a constant κ, the equation of van der Waals results. The present author claims to have discovered a remarkable property inherent in this equation, namely, that of giving very simply the expression of the free energy I as a function of its normal variables: volume and temperature. The energy thus expressed is one of the four functions of

Massieu, each of which suffices for determining all the properties of a body. The free energy is found to be $-I = RT \log (\nu - \alpha) + \phi(T)/(\nu + \beta) + \Phi$, where the last term is a function of the temperature, introduced by the integration and determined by means of the perfect-gas theory. If the volume ν increases progressively at constant temperature, the body approaches the state of the perfect gas, α becomes negligible in comparison with ν, and the above formula reduces to $-I = RT \log \nu - \Phi$, which is that for the perfect gas. If S be the entropy and c the molecular thermal capacity at constant volume (which is a constant for all perfect gases of the same molecular complexity), then $S = -(\partial I/\partial T)\nu = R \log \nu - \frac{\partial \Phi}{\partial T}$, $c = T(\partial S/\partial T)\nu = -T\frac{\partial^2 \Phi}{\partial T^2}$ and by integration $-\partial\Phi/\partial T = c \log AT$, whence $-\Phi = cT \log AT - cT - B$. The value thus obtained for Φ is substituted in the above formula for the free energy, whereby a complete expression for the free energy of a body has been derived from the Clausius equation of state. The author then proceeds to derive important consequences from the free-energy formula. The expression for C_ν represents observed facts better than that from van der Waals' equation. The application of the entropy formula to the study of saturated fluids provides most interesting results, and the latent heat equation receives detailed attention. If $\alpha + \beta = \gamma$, $x = (27/8) \cdot \nu RT/\phi(T)$, $y = (\nu + \alpha)/\gamma$, $z = 8\gamma p/RT$, then the equation of state reduces to $z = 8/y - 27/x(y + 1)^2$, and represents the idea of corresponding states as propounded by van der Waals. If y_1 and y_2 represent the vapour and liquid states of the fluid respectively, and if $\lambda = \log y_1/y_2$, then the latent heat equation takes the very simple form $L = \lambda RT$ when the function ϕ is replaced by a constant in the general equation $L/T = R\lambda + 1/\gamma \frac{\partial \phi}{\partial T}\left(\frac{1}{y_1+1} - \frac{1}{y_2+1}\right)$. When $x = T/T_c$, knowledge of the critical temperature T_c suffices to determine the latent heat of vaporisation at every temperature. Data are quoted with respect to the monatomic gases argon, xenon, and helium. [*Erratum.* Ibid. 164. p. 128, Jan. 8, 1917.] H. H. Ho.

522. *Upon a Form of the Temperature-function in the Clausius Equation of State.* **E. Ariès.** (Comptes Rendus, 163. pp. 963–966, Dec. 26, 1916.)—Clausius has been led to ascribe the form κ/T for carbonic acid to the function $\phi(T)$ of his equation. Sarrau has extended the use of the same function to oxygen, nitrogen, methane, and ethylene, and has been enabled to calculate the values of the constants κ, α, β in such a way as to represent the compressibility of the above five gases in accordance with the very exhaustive experiments of Amagat. These primary results have caused a very real importance to be attributed to the equation of Clausius. It is certain, however, that the more general formula $p = RT/(\nu - \alpha) - \kappa/T^n(\nu + \beta)^2$, where the exponent n is determined experimentally, will be more adapted to give a satisfactory representation of observed facts. This generalisation, far from complicating the investigation of the equation for any substance in general, on the contrary simplifies the problem while assuring an accurate solution. The reduced variables [see preceding Abs.] are in this case, $x = (27\gamma R/8\kappa)T^{n+1}$, $y = (\nu - \alpha)/\gamma$, $z = 8\gamma p/RT$, and the latent heat equation becomes $L/RT = \lambda - (27n/8x)[1/(y_1 + 1) - 1/(y_2 + 1)]$. The latter formula, together with the Clausius table, permits the calculation of the constant n for a body where only the critical temperature and a few heats of vaporisation are known, without having recourse to evaluating the constants α, β, κ in the equation of state. By trial of some exponents and by successive approxi-

mations it is possible to find a value of n which is in satisfactory accord with both the calculated and experimental data. This method also permits the constants α and β to be determined separately, and so is superior to the method previously in vogue. The author opines that the form κ/T should not be ascribed *a priori* to the function ϕ, but that substances should be classified in series for those where the exponent n is the same. The separation of γ into its two parts α and β offers some difficulties. The number n being fixed, the values of κ and γ are found to be $27R^2T_c^{n+2}/64P_c$ and $RT_c/8P_c$ respectively. Now α (the co-volume) $= v_c - 2\gamma = v_c - RT_c/4P_c$, but as the experimental determination of v_c is uncertain, it is better to put $v_c = N\alpha$, whence the relation $P_c v_c/T_c = \frac{NR}{4(N-1)}$ is obtained. If $\beta = 0$, $N = 3$ or ∞, and $P_c v_c/T_c = 3R/8$ or $= R/4$ respectively, whence $P_c v_c/T_c$ remains between limits which only vary by R/8, confirming Clausius and Sarrau in their conclusion that an exact evaluation of the co-volume was unimportant in the equations of state. The author then shows that T/T_c, p/P_c, and v/v_c have the same value for all substances in the same series. This is an important amendment of van der Waals' law of corresponding states, since the question of n series is now introduced. The author then shows that when β is not zero, yet for the same series the law of corresponding states holds. H. H. Ho.

523. *The Law of Molecular Entropy for Fluids taken at some Corresponding States.* **E. Ariès.** (Comptes Rendus, 164. pp. 134–138, Jan. 15, 1917.)—From the equation of state adopted in a previous paper [see preceding Abs.] numerous consequences may be deduced, one of the most important having to do with the entropy of a fluid the expression for which becomes: $S = R \log (v - \alpha) - n\kappa/[T^{n+1}(v + \beta)] + c \log AT$. Corresponding states of bodies have been defined earlier with respect to the series in which substances are classified, and the author now deduces that the variation of the molecular entropy, compared at corresponding states, is the same for all bodies of like atomicity. This proposition is not new, but a vigorous proof has not been presented hitherto, and the present demonstration is based upon the validity of the general equation of state $p = RT/(v - \alpha) - \kappa/T^n(v + \beta)^2$. The molecular calorific capacity, whether at constant volume or constant pressure, is next found to be the same for all bodies of like atomicity, taken at corresponding states. Following this comes the deduction that for all bodies of like atomicity the temperature of inversion has an invariable ratio with the critical temperature, while the expression pv/T has the same value at corresponding states. Finally $T\alpha_p$, $p\varepsilon_T$, $p\varepsilon_s$, and h/v are similarly established. H. H. Ho.

524. *The Law obeyed by the Four Functions of Massieu for Substances at their Corresponding States.* **E. Ariès.** (Comptes Rendus, 164. pp. 261–264, Feb. 5, 1917.)—In a previous note [see preceding Abs.] it has been shown that the unique fundamental law of van der Waals involves ten supplementary expressions, namely: L/T, pv/T, $T\alpha_v$, $T\alpha_p$, $p\varepsilon_T$, $p\varepsilon_s$, C_p, C_v, l/p, h/v, which have respectively the same values for all bodies of the same atomicity taken at corresponding states. The consequences, however, of so prolific a law do not cease there. The total differential of the entropy may be expressed as a function of temperature and volume, viz., $dS = (\partial S/\partial T)_v dT + (\partial S \partial v) dv$, which takes the forms $\partial S = c_v dT/T + l dv/T = c_v dT/T + l p \,.\, pv/T \,.\, dv/v$, and also may be expressed as a function of the independent reduced variables

$x = T/T_c$ and $y = v/v_c$, viz., $dS = c_v\, dx/x + lp\, pv/T \,.\, dy/y$. According to three of the expressions cited above, c_v, l/p, and pv/T are three different functions of reduced variables, but identical for all bodies of like atomicity, so that dS is the differential of a single function $f(x, y)$. Therefore by integration the difference of entropy for all bodies of like atomicity compared at corresponding states (x, y) and (x_0, y_0) is $S - S_0 = f(x, y) - f(x_0, y_0)$. This entropy expression has been found without recourse to any particular equation of state. Similarly the calorific capacities of vapours and liquids in a state of saturation, as also the temperature of inversion, may be deduced. The author next proceeds to discuss the energy expressed as a function of its normal variables S and v, and deduces that the difference of energy divided by the critical temperature is the same for all bodies compared at corresponding states. If this latter expression has a unique value for all bodies at one of the arbitrarily chosen states, it will preserve a unique value at every other state. This may serve to throw some light on the still obscure question of the absolute value to be attributed to the four entropy-functions of Massieu. Only differences of entropy can be measured, and while some scientists regard such absolute quantities as without special significance, the present author holds the opposite view and believes that the absolute evaluation of such quantities as entropy and energy will open out a new field for the study of the inter-relationship of bodies and for forecasting the course of a chemical reaction. The author then proceeds to develop his point of view from the standpoint that entropy and energy divided by the critical temperature have the same values for all bodies of like atomicity taken at corresponding states. The three other functions of Massieu, I, H, J, are related to the energy U by the relations, $I = U - TS$, $H = U - TS + pv$, $J = U + pv$, from which the author deduces that these four functions divided by the absolute temperature have the same value for all bodies of like atomicity taken at corresponding states. Following this comes a deduction that the temperature of the triple point is in an invariable ratio with the critical temperature for all bodies of like atomicity. H. H. Ho.

525. *The Entropy of a Perfect Gas at Absolute Zero.* **E. Ariès.** (Comptes Rendus, 164. pp. 343–347, Feb. 26, 1917.)—The author commences by stating that sufficient attention does not appear to have been directed to the choice for all bodies of a common initial state easy to reproduce, and from which their entropy and energy will be measured. One is led to a judicious selection of this state by Clapeyron's formula which gives the heat of vaporisation L of a body when condensed into the solid or liquid form, namely: $\partial P/\partial T = \Delta S/\Delta v = L/T\Delta v$. One of the facts best established by experiment is that the variation of entropy ΔS and of volume Δv, for passage from the condensed state to that of a saturated vapour at fixed tensions (P,T), are two quantities essentially positive. At temperatures superior to the triple point, the stable state corresponds to the vaporisation of the liquid, and at lower temperatures to the sublimation of the solidified body. To the degree that the temperature is lowered, the volume of the body entirely transformed into vapour increases without limit and finally becomes sufficiently large for the saturated vapour to be considered a perfect gas. If the temperature continues to fall, the tensions P and T will be henceforward dependent on the volume v of the vaporised body according to the relations: $Pv = RT$ and $\lim (P/T)_{T=0} = 0$. The pressure supported by the body, when entirely in the solid state, not only tends towards zero with the temperature, but becomes infinitely small compared with this temperature, signifying

that the saturated vapour-tension curves referred to the axes OP and OT is tangential at the origin to the temperature axis. This stable but limited condition of the solidified body is adopted as the initial state. By definition, the energy and entropy of this body are zero. No external pressure will then be exercised at absolute zero, and should any vapour be emitted it will be so rarefied as not to exist in any appreciable quantity in a finite volume. Finally all bodies are in the same condition with respect to corresponding states for the application of van der Waals' principle. Interesting conclusions are next drawn from these simple considerations. A belief very widely held is that the entropy of a perfect gas becomes infinite in a negative sense as its temperature tends towards absolute zero, while its volume or pressure would remain invariable. This proposition is shown to be invalid and a new one established, viz., that the increase which the entropy of a solid body experiences, in order to remain entirely vaporised at a low temperature in the state of a perfect gas, tends towards the constant R when the temperature approaches absolute zero. The consequences involved in this very important proposition are then indicated, as follows :— The heat of vaporisation vanishes at absolute zero, and the transformation from solid to vapour requires no work, whereby there results the fact that the energy of the body is the same in the two states. The free energy and the potential of a perfect gas are not functions of the temperature alone, except in the case where the gas is to be considered as a saturated vapour. Massieu's four functions tend towards zero with the absolute temperature for a saturated vapour which assumes the perfect state, but the ratios of these functions at the absolute temperature, *i.e.* of their differentials, tend towards given positive values. H. H. Ho.

526. *On the Quanta of Space Radiation.* **A. Rubinowicz.** (Phys. Zeits. 18. pp. 96–98, March 1, 1917.)—Debye has previously derived the Planck radiation law [see Abs. 1180 (1911)] by an elegant method which dispenses entirely with resonators. He considers the enclosed electromagnetic radiation in a Jeans's cube, and makes the assumption that the amount of energy given out at the separate degrees of freedom is equal to a multiple of an energy quantum. For the case of max. entropy, the spectral energy distribution in the cube is then given by Planck's formula.

The present author now shows mathematically that Debye's presentation of the energy quanta may be applied to space radiation when the recent assumptions of Sommerfeld and Planck for several degrees of freedom are accepted. Debye's standpoint is also shown to be free from objection throughout. The method used was foreshadowed by Sommerfeld and Epstein, and consists in searching for those canonical variables by which the Hamilton–Jacobian partial differential equations belonging to the problem in hand may be integrated by separation of the variables. Canonical variables and Hamiltonian functions may be used for space radiation in simple cubes without difficulties. Every electromagnetic process can be regarded as a superposition of the separate vibrations of the components of the system, as with a mechanical system. Application of the method may be made to any kind of defined space. H. H. Ho.

SOUND.

527. *Discontinuous Wave-motion.* II and III. **C. V. Raman** and **A. Dey**. (Phil. Mag. 33. pp. 203–207, Feb., and pp. 352–357, April, 1917.)—II. In an important paper on the theory of discontinuous wave propagation, Harnack has given an elegant general formula expressing the mode of vibration of a string whose configuration is completely determined by a finite number of discontinuous changes of velocity travelling over it. As an illustration of his result, Harnack has discussed, in some detail, the cases in which the form of vibration is determined by one and by two such changes of velocity respectively. The analysis indicates that the case of a single discontinuity is identical with that of the principal mode of vibration of a bowed string, and in a previous communication by one of the present authors [Abs. 352 (1916)] it has been shown how this mathematical result may be confirmed experimentally. The general case of two discontinuities considered by Harnack covers a considerable and interesting variety of forms of vibration, and the method described in the previous paper has now been successfully extended so as to obtain an experimental confirmation of Harnack's results in some of these cases also.

In these experiments, the characteristic vibration-forms produced by the motion of two unequal discontinuous changes of velocity of opposite sign have been observed and recorded photographically. Some are of the symmetrical type and the others are asymmetrical. The results are in full agreement with the mathematical theory first given by Harnack. The vibration-curves are found to be intermediate in form between those characteristic of bowed and of plucked strings. The cases in which the discontinuities are of the same sign are also of special acoustical interest and will be studied separately. The paper includes a plate with seven reproductions of photographic records of the vibrations.

III. This third paper deals experimentally with the cases in which two discontinuous changes of velocity having the same sign define the form of vibration. The photographic plate included in the paper gives eight reproductions of the vibrational types observed including in each case the initial motion. E. H. B.

528. *Doppler's Principle and the Whistling of Projectiles.* **E. Esclangon.** (Comptes Rendus, 163. pp. 289–291, Sept. 18, 1916.)—On certain assumptions it is shown mathematically that to a fixed observer near the trajectory of a high-speed projectile the Fourier components of its whistling sound have their frequencies determined by Doppler's principle but that the coefficients of the components vary periodically, hence the quality of the sound varies more or less rapidly. And this is what is observed when such a projectile passes close by. E. H. B.

529. *Sound Areas of Great Explosions.* **C. Davison.** (Nature, 98. pp. 438–439, Feb. 1, 1917.)—Explains the regions where the recent explosion in East London was heard and not heard, so far as is known. The author also requests that further accounts of the explosion being *heard*, and especially of its being *not* heard, at various localities may be sent to him at 16, Manor Road, Edgbaston, Birmingham. E. H. B.

ELECTRICITY AND MAGNETISM.

THEORY, ELECTROSTATICS, AND ATMOSPHERIC ELECTRICITY.

530. *Units and their Dimensions.* **J. B. Pomey.** (Rev. Gén. d'Él. 1. pp. 563–569, April 14, 1917.)—The author gives the definitions of the electrostatic and electromagnetic units. He then shows that if we are to keep the c.g.s. system these systems of units are incompatible with one another. He is thus led to introduce a new fundamental unit, and he chooses the dielectric coefficient (specific inductive capacity). The symbols for the fundamental units being M, L, T, and K he deduces the dimensions of the other units and discusses the homogeneity of the fundamental equations.

Brylinski [Abs. 322 (1917)] proposed that we should make either the unit of current or the unit of resistance a fundamental unit. A. R.

531. *Magnetic Hysteresis in van der Waals' Equation and Kinetic Theory.* **J. R. Ashworth.** (Phil. Mag. 33. pp. 334–352, April, 1917.)—The author previously showed that the relation of ferromagnetism to paramagnetism may be regarded as analogous to that of a liquid to its vapour [see Abs. 379 (1916)]. This idea is now further developed mathematically and the hysteresis cycles are plotted. E. H. B.

532. *Theory of Electricity and of Gravitation.* **E. Reichenbächer.** (Ann. d. Physik, 52. 2. pp. 134–173 and pp. 174–178, March 6, 1917.)—An interesting mathematical treatment following up the work of Mie and of Einstein [Abs. 782 (1912), 853 (1916)]. A. W.

533. *The Existence of Sub-electrons.* **R. A. Millikan.** (Phys. Rev. 8. pp. 595–625, Dec., 1916.)—The original paper corresponding to Abs. 1371 (1916).

534. *Delineation of Electrical Fields.* **J. Spielrein.** (Archiv f. Elektrot. 5. pp. 244–254, 1917.)—In a previous article [Abs. 232 (1916)] the author has shown by vector analysis how the change in the magnitude of a field vector depends on the curvature of the lines of force and the mean curvature of the potential surfaces. This problem is now handled by simple geometrical means, and equations are obtained by the aid of which it is possible to check the correctness of an assumed distribution of the lines of force and potential surfaces in any special case. The method is applied to a number of particular cases. Four main equations are obtained; they are as follows:—(i) $(1/E)(\partial E/\partial n) = k$, where E is the magnitude of the field vector, n the distance between the lines of force, and k the reciprocal of the radius of curvature of the lines of force, (ii) $(1/E)(\partial E/\partial t) = -H$, where t is the distance between surfaces orthogonal to the tubes of force and H is the mean radius of curvature of the orthogonal surfaces, (iii) $f/l = \Phi/P = \text{const.}$, where f is the area of the tube of force, l the distance between the orthogonal surfaces, Φ the flux per tube, P the p.d. between the orthogonal surfaces; (iv) $\partial H/\partial n + \partial k/\partial t = k/N$, where the terms on the left-hand side represent curvatures and N is the radius of curvature of the normal section of the potential surface perpendicular to the osculating plane to the line of force. In applying these formulæ to particular cases it is shown that equation (iii), which is often used alone, is not a sufficient criterion, and should be supplemented by the tests afforded by

the other equations if accurate fields of force are to be plotted. This is exemplified by inaccurate fields drawn by Kuhlmann in an article on the design of insulators [Abs. 774B (1915)]. A. J. M.

535. *Problems in Connection with the Pyro- and Piezo-electricity of Crystals. III. Experimental Determination of the Permanent Centric-symmetrical Moments.* **W. Voigt.** (Phys. Zeits. 18. pp. 59–67, Feb. 1, 1917.)—In two previous investigations [see Abs. 1374 (1916)], the author has discussed crystals whose volume elements possess electric moments of the second order (*i.e.* of centric symmetry) if temperature changes or deformations take place. The comparison of the centric with the earlier investigated asymmetric, or polar, disturbances has brought forth many interesting contrasts. Both these electrical phenomena occur in a twofold manner. In the original (homogeneous) state, the inner elements or molecular moments are compensated with respect to their activity by a surface charge upon the crystal. By thermal change or mechanical deformation the purely geometrical relations so change that this compensation no longer occurs and the inner moments become active. In addition, the above alterations cause the inner moments themselves to change, and these effects are superposed upon the former. There arises the question, which is important in the modern theory of crystal structure, whether it is possible, from the observation of pyro- or piezo-electric phenomena, to separate the two effects in such a manner as to draw conclusions on the nature and magnitude of the original or permanent molecular moments. This problem was not solved by the earlier eccentric, or polar, experiments, but the latter investigation indicated that the centric phenomena might afford data for this purpose. A detailed mathematical investigation is then given by the author. The conclusion is drawn that from the phenomena of centric-symmetric piezo-electricity produced upon bent and drilled circular cylinders, the three constituents of the permanent spacial electrical moments of a crystal permit of their determination to a common additive constant. Thereby is realised for a special case the principal conclusion deduced from general considerations obtained from the earlier investigation. The centric-symmetric phenomena thus behave throughout in a manner different from the earlier polar piezo-electricity—a result arrived at by examining the permanent spacial moments at hand in the crystal. H. H. Ho.

DISCHARGE AND OSCILLATIONS.

536. *Photoelectric Potentials for extremely Short Wave-lengths.* **P. E. Sabine.** (Phys. Rev. 9. pp. 210–219, March, 1917.)—The paper is a preliminary report of an investigation to determine the max. photoelectric potential produced by light in the Schumann region of the spectrum as a function of the frequency. Referring to Millikan's work on the voltage-frequency relationship expressed in Einstein's formula ($V = h/iv - V_0$), the work up to date is summarised. A special set of experiments is now described to find out how the voltage-frequency relation depends on the condition of the metal surface, concluding that the change in max. voltage for a given change in frequency is independent of the surface conditions of the metal, provided these conditions remain constant during the measurements. The effects produced by *scattered* light of short wave-length are also carefully investigated, since this effect is capable of introducing a large error into the measurements. Taken as a whole, the values of the photoelectric potentials for $\lambda 1250$ when compared with the results of other investigations, while not

affording a very accurate determination of Planck's h, nevertheless give reason to suppose that h/e is the slope of the voltage-frequency line for zinc and cadmium. A. B. W.

537. *Glow Discharge in Air.* **E. Reiche.** (Ann. d. Physik, 52. 2. pp. 109–133, March 6, 1917. Dissertation, Greifswald.)—Describes research on the conditions governing the commencement of the glow discharge in air. Owing to disturbing phenomena accompanying the discharge, most probably the formation of electric double layers by means of gas ions remaining in the gas film of the electrodes, deceptive values of the discharge potential can be obtained, which are much too high. Though these double layers are destroyed by intense discharges, they are strengthened by weaker currents, and hence give rise to hysteresis phenomena of the glow discharge. In general the weak current of a glow discharge that is just commencing causes a strengthening of the double layer opposing the field. The consequence is that with potentials only slightly above the discharge potential the usual glow discharge does not occur, but a discharge occurs lasting only for a very short time. Considerably higher potentials are required to produce the continuous glow discharge. [See Abs. 1426 (1903).] A. W.

538. *Free Vibrations of a Lecher System.* IV. **F. C. Blake** and **C. Sheard.** (Phys. Rev. 9. pp. 177–192, March, 1917. Paper read before the Am. Physical Soc., Dec., 1915.)—This paper, following upon the third of the series, reports upon the effect of the presence of the wooden supports for the capacity plates upon the phase relations and the relative wave-lengths of the various tones. The influence of the edge-on distance between the plates upon the wave system is also dealt with. E. H. B.

ELECTRICAL PROPERTIES AND INSTRUMENTS.

539. *Light and Electricity in Selenium.* **H. Greinacher.** (Deutsch. Phys. Gesell., Verh. 18. 4. pp. 117–134, 1916.)—Experimenting together with C. W. Miller with four selenium cells of the Shelford Bidwell type (which differed in their properties) and a Wheatstone bridge, the author observed that continuous currents sent through the cells in the dark increased the resistance, that the increase was not the same for positive as for negative currents, that the difference increased when the current flowed for long periods, and that the cells therefore behaved like rectifiers. When continuous currents were first applied and alternating currents then superposed, the galvanometer was deflected in the opposite direction to the deflections observed when continuous currents were alone used; with respect to alternating currents the selenium cells behaved as under light-excitation. Having investigated the influence of potential, time (inertia) and temperature, and also tried radiotelegraphic (Telefunken) currents, the author concludes that the action of light on selenium is a special case of the effect of alternating currents. Reference is made particularly to C. Ries. **R. Fürstenau.** (Ibid. 18. 6/7. pp. 184–186, 1916.)—Using an arrangement similar to that of Greinacher, Fürstenau has never observed any of the continuous-current effects of the former in testing many hundred selenium cells from the Radiologie firm, Berlin. There was no polarity and no rectifying effect, and the resistance of the cells remained quite constant when they were under current in the dark for 60 minutes. Greinacher himself considered one of his cells as abnormal; the author suggests that they were all abnormal. H. B.

540. *Thermal and Electric Conductivity of some Metals at Low Temperatures.* **R. Schott.** (Deutsch. Phys. Gesell., Verh. 18. 1. pp. 27–34, 1916.)—The paper was prepared by A. Eucken, the author having been killed in the war. A vertical rod of the respective metal, 5 cm. high, 0·5 cm. diam., is soldered to a copper plate and heated by a resistance soldered to the top of the rod; thermo-couples are soldered to the rod at two points, and the temperature gradient is thus determined. The apparatus is placed within a glass cylinder. Measurements were taken, at 273°, and at or near 90°, 80° and 20° C. abs., on Cu, Al, Cd, and Pb. Aluminium, only tested thermally, gave a lower conductivity as the temperature was lowered. In the case of the other metals and especially of copper (4 samples, (i) a pure crystal, (ii) pure coarse crystals, (iii) fine crystalline, nearly pure, (iv) same, less pure) the thermal conductivity λ and the electric conductivity κ increased very greatly as the temperature was lowered, and the ratio $\lambda \times 10^8/\kappa T$ decreased in all the four copper samples, but not in the same way; the values were at 273°...2·42, 2·33, 2·24, 2·28 for the samples in the order stated, and at 21°...1·21, 0·35, 1·47, 1·97. The conclusion is drawn that the λ values cannot depend on the electrons alone, for the electronic conductivity λ_e should have the same value for the different samples at the same temperatures, but must be influenced by the crystal conductivity λ_κ. **W. Meissner.** (Ibid. 18. 9. pp. 240–245, 1916.)—Meissner, to whom Eucken had referred, uses at the Reichsanstalt the Kohlrausch-Diesselhorst method which gives λ and κ at the same time [see Abs. 1694 (1915)]. Correcting a few misprints in his paper just quoted he criticises the conclusion drawn by Schott and Eucken, also the apparently implied assumption that the ratio λ/κ should be the same for copper specimens differing in purity. **A. Eucken.** (Ibid. 18. 15/16. p. 364, 19/16) briefly replies. H. B.

541. *Variation of the Thickness of a Layer of Indiarubber under Influence of an Electrostatic Field.* **L. Bouchet.** (Comptes Rendus, 163. pp. 479–481. Oct. 30, 1916.)—It has been pointed out previously that solid insulators dilate normally to the electrostatic field. To make the knowledge of this phenomenon more complete it was necessary to study the behaviour in the direction of the lines of force; in order to do this, rubber is chosen as the insulating substance. Discs 15 cm. diam. of varying thicknesses are used; a disc of brass is fastened to one of the faces with paraffin and a thin piece of Al or tin-foil is put on the other face. When a field is created between the armatures of this condenser the rubber is deformed, (1) under the action of the electrostatic pressure; (2) to this deformation a contraction or a dilatation may be added, caused as a direct action of the field. If e is the thickness of the rubber, K its apparent dielectric constant, E its Young's modulus, V the p.d. between the armatures, and Δe the variation of thickness, the contraction due to electrostatic pressure is given by $\Delta e = KV^2/E8\pi e$. A table giving values of Δe shows that for the specimen of vulcanised rubber the contractions observed are larger than those calculated; the differences representing the direct effect of the field increase very nearly as the square of the p.d.'s. In the case of the pure rubber the action proper of the field is not so apparent. An enormous residual deformation of this specimen is, however, noted. In order to make the action of the field more easily discerned a series of five superposed condensers is used and results are then obtained which confirm the results of the first experiments. It thus appears to be established that under the action of an electrostatic field, vulcanised rubber contracts in the direction of the lines of force. A. E. G.

542. *Validity of Ohm's Law for High Current-densities.* **H. v. Traubenberg.** (Phys. Zeits. 18. pp. 75–78, Feb. 15, 1917.)—Lecher has previously shown that Ohm's law holds up to current densities of $1{\cdot}4 \times 10^4$ amps./mm.^{2}. He made use of a silver wire 0·03 mm. in diam. placed in rapidly flowing water. In the research here described an oscillatory circuit was employed, including capacity and self-induction, two micrometer spark-gaps being used, one on either side of the condenser. The wire under investigation was placed as a shunt across one of the spark-gaps, and so currents of very short duration could be dealt with. In this way it was shown that, within the possible errors of observation, Ohm's law is valid for current densities up to $10{\cdot}5 \times 10^4$ amps./mm^2. A. W.

543. *Surface Electric Double-layer of Solid and Liquid Bodies.* **J. Frenkel.** (Phil. Mag. 33. pp. 297–322, April, 1917.)—The paper commences with a discussion on Intrinsic Potentials. It has been assumed by many investigators on contact e.m.f.'s that these are due to the presence of electric double layers on the surface of metals, the existence of which has been conclusively established by experiments on the thermionic and the photoelectric effect. Richardson has shown that the free electrons, in escaping from a heated metallic body, perform a perfectly definite amount of work at the cost of their kinetic energy due to thermal agitation, which work is measured by the constant ω in the formula $i = A\sqrt{(T)}e^{-\omega/\kappa T}$; where i is the thermionic current, T the temperature, and κ the gas constant. The fact that ω is always positive shows that the electric force near the surface of all metals is directed outwards (thus tending to keep the electrons back), *i.e.* the outer face of the electric double layer is always negative and the inner positive. The electric potential inside the metallic body must therefore exceed that of its environment by a positive quantity V, connected with ω by the relation $eV = \omega$, where e is the electronic charge, and V may be called the intrinsic potential of the body. The difference between the intrinsic potentials of two metals must be equal to their contact e.m.f. (neglect being made of the Peltier-effect), a fact which has been verified in a few cases by comparison of the theoretical values, obtained from the thermionic data, with those directly measured by the electrostatic method. The author next takes up the question of the origin of these electric double layers. The old view, which favoured an external origin depending upon occluded gases, chemical action, etc., is now being supplanted by the opposite view, which, leaving to the external agencies but a secondary rôle, tends to trace the origin of intrinsic potentials to the action of some intrinsic cause, more appropriate for the explanation of their comparative constancy. It is the main purpose of this paper to show that such a cause really exists, and the author opines that its extreme simplicity is, perhaps, the only reason why it has not been noticed until now. Assuming the atoms to consist of positive nuclei with electrons rotating about them, it is shown that these electrons constitute over the surface of metals a layer of negative electrification with a corresponding layer of positive electrification on the inner side of the surface, the electric double layer of atomic thickness, thus formed, preventing the free electrons from escaping. The distribution of electric charge, intensity, and potential in the double layer is calculated and the results are generalised for all liquid and solid bodies. The intrinsic potentials of metals are found to be always positive, to be of the same order of magnitude as the corresponding ionising potentials, and to tend to increase with their valency. Tables

giving the intrinsic potential of the atomic double layer for a few metals are added. The potentials amount to a few volts only, and the valent electrons are the only effective ones in their production. The section concludes with a brief discussion on the electrification of insulators and electrolytes. Insulators are distinguished from conductors by the absence of free electrons, and not by the absence of intrinsic potentials, which in this case may be positive as well as negative, depending upon the structure of the molecules. It is shown that the contact e.m.f. of metals and dielectrics is due to the difference of their intrinsic potentials.

Part II of the paper deals with the surface tension of liquids. The phenomena of electro-capillarity disclose an intimate relation between contact e.m.f.'s and surface tension. On the present theory both the latter are due to the same cause—the atomic (or molecular) electric layer enveloping the surface of solid and liquid bodies—the first depending upon its intrinsic potential, and the second upon its energy. That a certain portion of the surface tension must be due to this energy immediately follows from the fact that the latter is proportional to the surface of the body. The considerable effect produced upon the surface tension of mercury by the secondary electric layers which are formed when it is in contact with an electrolyte shows that this portion may be very large, and the author proceeds to make an estimate of it, beginning with metals. He finds that the surface tension of liquids is wholly accounted for by the energy of their atomic electric double-layers. The atomic radii and intrinsic potentials are calculated for a a number of metals from their surface tension, tables being given. The intrinsic potentials thus calculated amount to a few volts, and permit the metals being arranged in Volta's series, while the atomic radii are very nearly equal to those corresponding, on Bohr's theory, to stationary orbits of second order. The small surface tension of dielectrics, compared with metals, is explained, and the surface tension of liquid hydrogen is correctly calculated by means of Debye's model. The normal stress in the double layer is calculated, and its connection with the internal pressure of liquids pointed out. The fact that the energy of the surface electric double-layer is sufficient to account for the surface tension indicates that the latter does not directly depend upon cohesive forces. When a neutral atom (or molecule) escapes from the liquid, the energy lost in crossing the surface layer is equal to the work of cohesive forces only, and therefore the electric double layer does not affect the vaporisation heat, although it permits of its calculation provided the above-mentioned connection between the electric stress and the internal pressure is correct. H. H. Ho.

544. *Simple Demonstration of the Ampère Molecular Currents.* **A. Einstein.** (Deutsch. Phys. Gesell., Verh. 18. 6/7. pp. 173–177, 1916.)—A modification of the experiment by the author and de Haas [Abs. 1123 (1915)]. An iron rod, 10 cm. long, 1·4 mm. diam., is suspended by a quartz fibre of 10 μ within a field formed by two coils in series so that the mirror on the rod is in the gap between the two coils. A small magnet is approached to start oscillations in the rod, and the field is then reversed by means of a commutator, the circuit being closed each time only for about 0·001 sec. The compensation of the terrestrial field and the suspension of the rod proved very troublesome; the difficulties were overcome in the Reichsanstalt with the assistance of W. Jaeger. When the suspension is not perfect, the reversal causes the rod merely to tremble, but not to oscillate.
H. B.

545. *Electromagnet Moving-coil Galvanometers for Alternating Currents.* **E. Weibel.** (Bureau of Standards, Bull. 14. pp. 23–58 [Sci. Papers No. 297], 1917.)—A description of electromagnet moving-coil galvanometers for measurements on alternating currents and a presentation of the theory of their action. From the equations of motion of a coil carrying an alternating current in an alternating magnetic field it is shown that the deflection $\theta = GE \cos \beta/(RU)$, where G is the rate of change with the deflection of the effective value of the flux, E the effective value of the impressed e.m.f., β the angle of lead of the impressed e.m.f. ahead of the flux, R the resistance of the moving-coil circuit, and U the moment of restoration acting on the moving system. The motion is aperiodic if $R = G^2/[\sqrt{(4KU)} - D]$, where K is the moment of inertia of the moving system and D the moment of damping. The free period is $T = 2\pi\sqrt{K}/\sqrt{U}$ and the sensitivity in mm. deflection at 1 metre per microvolt is $S = 200{,}000\ [\sqrt{(4KU)} - D]/GU$. The effect of the presence of harmonics is to change the equilibrium position for no impressed e.m.f., the period, and the damping and to give a deflection proportional to the sum of the products of the harmonic flux and harmonic e.m.f. and the cosine of the angle between them. Disturbing torques are produced by electrostatic action between the coil, case, pole-pieces, etc., change of self-inductance of the coil as it turns, the presence of materials in the moving-coil system that have a finite susceptibility, capacity current between turns of the moving coil, leakage and capacity currents between parts of the moving-coil circuit and external bodies. These disturbing forces are discussed, and it is shown that they may for the most part be remedied by providing shielding arrangements. Particulars are given of the design of and tests on four sensitive instruments. The sensitivity is much greater than that of the telephone receiver at the lower frequencies, is greater than that of the vibration galvanometer, and is equal to that of the best d.c. moving-coil galvanometers. One instrument was used on a frequency of 2100 cycles per sec., and although it was very sensitive, difficulties were met due to unexpected oscillations of the moving-coil system. A. J. M.

546. *Static Method of Frequency Measurements in Alternating Currents.* **A. Heydweiller** and **H. Hagemeister.** (Deutsch. Phys. Gesell., Verh. 18. pp. 52–54, Feb. 15, 1916.)—Describes a method of frequency measurement by the use of a Wheatstone bridge of which three arms are non-inductive resistances R_1, R_2, and R_3, the fourth arm containing both self-induction, L, and capacity, C, as well as resistance, R_4. Any suitable measuring instrument forms the diagonal arm (in the case of high frequencies the telephone may be used), and the value of L and of C are adjusted until the null point is reached. Then $R_1(R_4 + i\omega L + 1/i\omega C) = R_2R_3$, giving $R_1R_4 = R_2R_3$ and $\omega^2 = 1/LC$, so that the frequency $n = 1/2\pi\sqrt{(LC)}$. The results of some measurements made by this method for frequencies of 1500 and 600 per sec. are given in the paper and show a very good accuracy. J. W. T. W.

547. *Static Method of Frequency Measurements in Alternating Currents.* **B. Thieme.** (Deutsch. Phys. Gesell., Verh. 18. pp. 195–200, April 15, 1916.)—The author criticises the null method of frequency measurement described by Heydweiller and Hagemeister [see preceding Abs.], and gives an account of a method depending on the electrolytic action of carbon electrodes in proximity to flames [see Abs. 540 (1912)]. The fine emission streams vibrate, under suitable conditions, in the period of the e.m.f. applied to the electrodes, and by a stroboscopic method the period may be observed up to about 15,000 vibrations per sec. J. W. T. W.

548. *Automatic Device for Charging Electroscopes.* **L. Kolowrat.** (Phil. Mag. 33. pp. 358–359, April, 1917.)

ALTERNATING CURRENTS AND MAGNETISM.

549. *Magnetic Induction and its Reversal in Spherical Iron Shells.* **J. W. Nicholson** and **E. Wilson.** (Roy. Soc., Proc. 93. pp. 129–148, March 1, 1917.)—In connection with previous work [Abs. 1289 (1916)], theoretical treatment gives the solution of certain problems which arise in the production of an effective shield for large spaces. The effects of indefinitely closely wound coils on the separate spherical shells of a magnetic shield are obtained by theory, and compared with the experimental values as found by means of an exploring coil and ballistic galvanometer. The results supply an estimate of the deviations of Maxwell's formula, for the field inside a spherically wound wire, from the true value, when the spacing of the wires in the helix is of importance. Further, the delay in the reversal of magnetic phenomena in considerable masses of iron, due to eddy currents, is extremely small when the magnetic inductions are less than 300 c.g.s. G. E. A.

550. *Magnetisation of Iron, Nickel, and Cobalt by Rotation.* **S. J. Barnett.** (Nat. Acad. Sci., Proc. 3. pp. 178–181, March, 1917.)—An extension of a previous investigation on iron [see Abs. 1466, 1761 (1915)] to other specimens of iron and to nickel and cobalt. The former method was modified to use an astatic magnetometer instead of the method of electromagnetic induction; also magnetic and mechanical disturbances and those due to variations of H were reduced as much as possible. Observations were made of the effect on the magnetometer of bars of the magnetic materials 30·5 cm. long and 2·3 to 3·2 cm. in diam., when rotated about 45 times per sec. first in one direction and then in the opposite, the rods being in a horizontal position normal to the magnetic meridian. The mean value of the effect measured was in all cases less than the theoretical, but it is considered that the experiments confirm the assumption that only electrons are in orbital revolution in the substance investigated. A more detailed account is promised. G. E. A.

551. *Determination of the Degree of Uniformity of Bars for Magnetic Standards.* **R. L. Sanford.** (Bureau of Standards, Bull. 14. pp. 1–14 [Sci. Papers, No. 295], 1917.)—This paper describes a method for investigating the degree of magnetic uniformity along the length of straight bars such as are used for magnetic standards, and gives the results of tests made on a number of such bars. The bar to be tested is clamped between the poles of a suitably designed electromagnet and two small exactly similar coils slide along the bar at a fixed distance apart. These coils may be connected in opposition, and when the circuit is completed through a ballistic galvanometer the throw on reversal of the magnetising current is proportional to the difference of induction at the two parts of the bar occupied by the coils. The average leakage over the space between the coils can thus be calculated. Uniform rate of leakage along the bar signifies magnetic uniformity. The curve showing rate of change of leakage along the length of the bar is termed the uniformity curve. An increase in the ordinate of this curve at any point signifies a magnetically hard spot, a diminution in the ordinate a magnetically soft spot. A photographic record of the rate of change of leakage along the whole length of the bar can be obtained by moving the coils along at a uniform rate. The uniformity curves are taken for inductions of 10,000 gauss at the centre of the bar. Higher inductions

raise the ordinates of the curve near the ends, and readings at lower inductions may be affected by the previous magnetic history of the specimen. Repetition tests on the same bar show the method is consistent. Curves are given for a number of bars of cast steel and annealed wrought iron. These all show want of magnetic uniformity although to the eye they were apparently homogeneous. A quantitative statement of the effect of the non-uniformities on the accuracy of magnetic measurements is difficult because the magnitude of the error depends upon a number of variables, *e.g.* the number, extent, and magnitude of the non-uniformity; the value of the induction; and the type of apparatus used for measurement. Normal induction measurements were made with a Burrows' permeameter on a number of bars which originally were approximately uniform. Non-uniformities were then artificially produced at the middle of the bar, as with this type of permeameter the effect is greatest when the non-uniformity is at the centre. The data obtained show that for any given induction the percentage error in the observed magnetising force is roughly proportional to the percentage deviation of the ordinate of the uniformity curve from the mean value. For an accuracy of 1 % variations in the value of the ordinate of the uniformity curve from the mean must not exceed 10 %. The apparatus may be applied to the detection of mechanical inhomogeneities and flaws. A bar originally uniform was bent about 10° in a vice and then straightened. A decided kink is shown in the uniformity curve where the bar was clamped, indicating a magnetically hard spot. After annealing the uniformity of the bar was greater than initially. L. L.

552. *On the Pulsatory Variations of Terrestrial Magnetism.* **T. Terada.** (Math. Phys. Soc., Tōkyō, Proc. 8. pp. 566–570, Dec., 1916. Abstract.)—In 1910 a temporary magnetographic station was erected at Misaki under the auspices of the Imperial Earthquake Investigation Committee. Observations were continued until April, 1914. The author investigated the characteristic pulsatory variations of the terrestrial field which had been already studied by Eschenhagen, Birkeland, and van Bemmelen. A summary of the results is here given.

(1) Periods range from about 20 secs. to several (ten) minutes. Those waves with the periods 30 to 300 secs., most frequent and conspicuous, appear in remarkably regular trains. Within the latter range of periods no very sharply defined maximum of frequency is observed except two rather flat relative maxima near 50–60 secs. and 90 secs. (2) The shorter waves with periods less than 70 secs. are most frequent during the daytime and near noon, while the longer waves of 90–300 secs. occur mostly at night. The occurrence of all waves 30–300 secs. has a maximum in the morning and a minimum in the evening hours. (3) The vertical component (downward taken positive) of the periodic field generally runs similarly to the meridianal component (northward taken positive) though with reduced amplitudes and certain phase retardations, depending on the periods. (4) The azimuth of the direction in which the horizontal component of the periodic field fluctuates, undergoes a characteristic diurnal variation, being in greatest deviations from the meridian generally a few hours before midnight and noon, and crossing the meridian in morning and evening hours. The variation is similar to that possible by fluctuations of a zonal atmospheric current, fixed with respect to the sun and with its pole considerably deviating from the earth's axis. (5) In general, however, the horizontal component of the periodic field shows more or less of a rotatory character. The sense of

rotation is subjected to a characteristic semidiurnal variation. The clockwise (N.–E.–W.) rotation is most frequent during the hours between sunrise and noon as well as between sunset and midnight, while the opposite rotation prevails in the remaining hours. (6) The daily frequency of the pulsations in question seems correlated with the sun's proper rotation, showing an apparent periodicity of 25–30 days' interval. The variation of the frequency suggests that the seat of pulsation is initiated on a limited portion of the sun's disc and influences terrestrial magnetism only when it is passing through a certain meridian of the sun's surface. Moreover, it would seem as if the source of disturbance remained in action only for a few rotations of the sun, being soon replaced by another appearing in another portion of the sun.

From a study of these facts and a comparison of different hypotheses, the author is at present inclined to believe that the most frequently observed waves with the periods 30–300 secs. are the result of the fluctuating electric current produced in a higher conducting layer of the atmosphere by the electromagnetic induction, due to the *vertical vibration* of a more or less limited portion of the atmosphere. The possibility of the vertical modes of vibration of an atmosphere with infinite horizontal extent, has already been shown by H. Lamb and S. Sano ; they both agree in arriving at a result that the natural period of our atmosphere may be of the order of 5 mins. The wide variability of the actual periods of the magnetic pulsations, as described in (1) and (2), may probably be accounted for in different ways, for example, by the different extents of the vibrating area and also by the probable laminar structure of the actual atmosphere as regards the temperature, wind velocities, etc., though the final decision must be postponed till a more complete mathematical theory has been developed on the vertical vibration of a finite portion of atmosphere, with more or less laminar structures. According to the author's hypothesis, result (3) may be explained, at least in its main feature, by the influence of the current induced in the earth's crust. Then (4) follows, if it is considered that in the magnetic field of the upper atmosphere, the component contributing to the regular diurnal variation of terrestrial magnetismis of importance, since the latter current may be represented, to a first approximation, by a zonal system of current inclined to the equatorial plane. Again (5) allows of the simplest explanation by the assumption that the current producing the magnetic waves is subjected to *see-saw motion* in the vertical plane, simultaneous with the fluctuation of the intensity of the current. In regard to the semi-diurnal variation of the sense of rotation no definite opinion is expressed, though the legitimate explanation, it is thought, will depend much on the results of mathematical investigations with regard to the different vertical modes of vibration of the atmosphere. Lastly, (6) may be reconciled with the present theory by assuming, after Schuster, that the solar corpuscular radiation results in increasing the conductivity of the upper atmosphere and making apparent the vibration already present in the atmosphere, by the induced current thereby produced.

It may be hoped that by pursuing the line of investigations suggested by the present results, a convenient clue may be found for following the daily or hourly change going on in the remotest part of the atmosphere, merely by means of magnetic observations. E. O. W.

553. *Magnetic Storm of August* 26–27, 1916. **W. E. W. Jackson.** (Roy. Astron. Soc., Canada, J. 11. pp. 17–22, Jan., 1917.)—An analysis is made of the magnetic records at Sitka, Meanook, Agincourt, Cheltenham, Tucson, and

Honolulu during the occurrence of the aurora and magnetic storm of August 26–27, 1916.

The beginning of the disturbance was very abrupt in H and D at all the stations, and from later comparisons with the records at Eskdalemuir it is evident that the effect occurred practically simultaneously all the world over. C. P. B.

RADIOGRAPHY AND ELECTROPHYSIOLOGY.

554. *New Coupling of Induction Coils.* **A. J. de Beaujeu.** (Archives d'Él. Médicale, 25. pp. 120–127, March, 1917.)—Induction coils in parallel or series offer no advantage in the production of X-rays, the intensity in the tube being very nearly the same, and there are certain difficulties to overcome. The most useful combination is a mixed one—primaries in parallel secondaries in series. The arrangement here described enables one to obtain an increase in the intensity in X-ray tubes. The system is based upon the following considerations : The max. effect is produced when induction coils are used with mechanical turbine interrupters. This maximum is characterised by a certain amperage in the primary, and the best number of interruptions per sec. of current, which number varies between 40 and 130 about, according to circumstances. If this number could be doubled or trebled, etc., then the intensity in the tube would be likewise doubled or trebled, etc. With the coils in use this is not possible on account of magnetic, self-induction and hysteresis effects which require a certain time for their production. There is thus time wasted between the interruptions. Apparatus and coupling is described to overcome this difficulty, and various diagrams are given to illustrate the methods employed. By the means described, several coils can be worked with one mechanical interrupter, and, by the aid of suitable valves, etc., the secondary current can be conveyed into a single tube so as to obtain an intensity in proportion to the number of coils used, or into several tubes simultaneously. A. E. G.

555. *The Electrical Elements on which the Production of X-rays Depends.* **G. C. Trabacchi.** (N. Cimento, 12. pp. 85–96, July–Aug. 1916.)—Beatty, and also Rutherford and Barnes [Abs. 245 (1914) ; 1417 and 1418 (1915)] have carried out experiments in this connection with tubes run by an absolutely constant current, such as is produced in electrostatic machines. In such instances it is clearly settled that while the penetrating power of the rays produced increases regularly with the tension applied to the tube, the energy of the rays is proportional to the product of the square of the tension V by the current i. This signifies that the energy of the rays with respect to the electrical energy Vi used up in the tube, increases in proportion to the tension V ; so it may be stated that the energy of the rays does not depend solely on the watts, but on the watt-volts supplied by the tube. The Cardini-Carter law indicates that the energy of the X-rays is proportional to the product VE of the discharge potential by the energy expended in the tube. In the case of constant currents this law is identical with the results of the experiments of Rutherford and Barnes. An examination of the diagrams given shows that whatever may be the apparatus employed, it is necessary, in order to obtain radiographic equivalents, to maintain the value of $V^n it$ constant, V being the max. tension measured by the spark equivalent, i the mean intensity, and t the time of exposure. A. E. G.

CHEMICAL PHYSICS AND ELECTRO-CHEMISTRY.

556. *Direct-reading Ionometer.* **F. E. Bartell.** (Am. Chem. Soc., J. 39. pp. 630–633, April, 1917.)—A description, which is not detailed, of a direct-reading potentiometer, which is so calibrated that the readings are given directly in terms of hydrion concentration. It is so constructed as to read from normal acid to normal base concentrations, that is, concentrations of hydrion varying from 1×10^{-0} to 1×10^{-14}. Other auxiliary electrodes besides the hydrogen electrode may be used, the necessary corrections being made on the instrument. A photograph of the ionometer is given, as also a table showing that it is capable of giving accurate readings. T. S. P.

557. *The so-called Antozone.* **V. Rothmund.** (Phys. Zeits. 18. p. 113, March 1, 1917. Paper read before the Deutsche. Bunsen Gesell., Dec., 1916.)—The whitish mists observed when ozone acts on iodides, sulphur dioxide, etc., had been attributed by G. Meissner to the antozone of Schönbein. The author finds that the mists only appear when ozone can react with some volatile product in the presence of water. Calculating the size of the mist spherules after Townsend, he finds that these sizes agree with those deduced from the velocity of their fall : in the case of potassium iodide too large values were found, however, probably because both iodic acid and hydrogen peroxide were formed. In general, ozone reactions of different nature seem to give rise to mists of the same properties. H. B.

558. *Magnesium.* **W. M. Grosvenor.** (Am. Electrochem. Soc., Trans. 29. pp. 521–526 ; Disc., 526–527, 1916. J. Indust. Eng. Chem. 8. pp. 275–276, March, 1916. Chem. News, 113. pp. 221–223, May 12, 1916.)—Magnesium is used as illuminant, as scavenging alloy in metallurgy, and, alloyed with Al and small quantities of other metals, as material for construction. Before the war the United States imported 38,000 lbs. of Mg per year at $1.45 per lb. (present price $5.50) mostly from Germany ; both France and England have since been producing very pure Mg. The chief manufacturing processes are : reduction of fused $MgCl_2$ with sodium (by the Castner process) ; electrolysis of some fused double chloride, generally $MgCl_2$, 2KCl, largely used abroad. Reduction with carbon yields a black powder ; this process looks very promising, but offers great difficulties. The author has tried the processes and new suggestions (electrolysis of dissolved MgO, reduction of fused $MgCl_2$ by Al, reduction of oxide or carbonate to slag-forming residues) and considers that magnesium has a great future, in the first instance also for military work (illuminating bombs, hot-rolled metal or alloy for construction of aeroplanes, etc.). H. B.

559. *Gas Analysis by Conductivity Measurement.* **F. Krüger.** (Phys. Zeits. 18. p. 112, March 1, 1917. Paper read before the Deutsche Bunsen Gesell., Dec., 1916.)—The highest conductivity and ionisation can be secured by means of α-rays, and if these be completely absorbed, the ionisation and saturation current will be independent of the nature of the gas. When the vessel is long, however, complete absorption might be secured in a dense gas, but not in a less dense gas, and the composition of mixtures of two gases can be deduced from the measurements of the currents, of the order of

10^{-9} amp. Ordinary resistances are unsuitable for this purpose. By kathode volatilisation of platinum and condensation of the vapour on amber the author has prepared a series of seven resistances ranging from 5×10^8 to 3×10^{13} ohms. By the aid of a differential arrangement he has analysed gas mixtures within 0·1 % and less. H. B.

560. *Adsorption of Gases by a Non-volatile Adsorbent.* **M. Polányi.** (Deutsch. Phys. Gesell., Verh. 18. 2/3, pp. 55–80, 1916.)—A mainly theoretical consideration. The attractive forces between the adsorbent and gas depend upon the character of the substance and the distance of the interacting molecules in the adsorption space which the author defines per gramme of adsorbent; a solution of the gas in the adsorbent is not assumed. The only data available for the verification of the formulæ are those of A. Titoff [Abs. 549 (1911)] on the adsorption of CO_2 by charcoal, as those observations cover a sufficiently wide range; in that case 1/30 of the adsorption space contained half of the adsorbed gas, the max. condensation was 2000-fold, and the pressure arising was 42 atmos. The conclusion is that, the adsorption isotherm having been determined for some temperature, the conditions of equilibrium as well as the gas concentration can be calculated for any other temperature and pressure, provided the constants of van der Waals be known. H. B.

561. *Metallographic Investigation of the System of Silver-Tellurium.* **M. Chikashige** and **I. Saito.** (Kyōtō Coll. Sci., Mem. 1. pp. 361–368, July, 1916.)—Mixtures of silver and tellurium in varying proportions but, in each case, of a total volume of 2·5 cm. were heated to melting in a porcelain tube placed in an Heraeus electric furnace. An atmosphere of hydrogen was maintained in the tube during the melting. Measurements of temperature were made by a Pt-Rh thermo-element which was first carefully calibrated, and the reguli obtained were examined micrographically. At the higher temperatures employed an allowance was made for the loss of Te by volatilisation. Maxima in the freezing-points were obtained with proportions corresponding to the formulæ Ag_2Te and Ag_7Te_4, and micrographical examination showed homogeneous crystallisation and absence of eutectoids with reguli of these compositions. Ag_2Te was obtained as a brittle greyish-white crystalline body melting at 957°, and corresponding to the natural mineral hessite. With excess of silver, the reguli contained no mixed crystals, and a eutectoid of Ag_2Te and Ag of minimum freezing-point separates at 865° and contains 87·5 % Ag. With excess of tellurium, Ag_2Te separates by primary crystallisation until a composition of 43 % Ag is obtained, when chemical reaction takes place to form β Ag_7Te_4 (containing 59·7 % Ag) which crystallises at 443°, and changes into the α form at 403°. Ag_7Te_4 does not form mixed crystals, but remains mechanically associated in the regulus with Ag_2Te, and is immiscible with Te in the solid state. A eutectoid of Te and Ag_7Te_4, melting at a minimum point of 334° is formed with a mixture containing 32 % Ag. No evidence is given of the formation of other compounds such as AgTe or Ag_3Te_2. Reguli with a content of about 70 % Ag consisting of Ag_2Te and Ag give alloys of fine structure and of possible technical importance. J. N. P.

562. *Allotropy of Silver.* **W. D. Helderman.** (Inst. of Metals, J. 16. pp. 84–117, 1917. Engineering, 102. p. 287; Discussion, 287–288, Sept. 22, 1916. Abstract.)—Having determined the density and volume of silver

submitted to various heat treatments, the author concludes that there are at least three varieties of silver, though he was not able to isolate them in a pure state; there is a transition-point at 77°. All objects of silver are in a metastable condition; the constants of silver (except the atomic weight) referring to indefinite mixtures of the different allotropic forms have to be redetermined.—In the *discussion*, the conclusions were severely criticised. **W. Rosenhain** pointed out that the silver turnings used would be cold-worked and hence probably in the amorphous phase, which would suffice to explain the observations; as the metal was immersed in water, water might have been taken up, Sears having shown that even polished weights of copper-nickel took up water; the absence of any differences in electric potential between the supposed allotropic modifications also spoke against the conclusions. **T. Turner** likewise missed real evidence of any allotropy although he thought that the effect of water would be less noticeable when the metal was immersed all the time. **E. A. Smith** mentioned that water-logged spongy gold had a density of 13 or 14 and did not recover its original density of 19 unless re-melted; gas absorption by the silver had also to be considered. **G. T. Beilby** wanted further investigation before expressing any opinion. H. B.

563. *Corrosion and Electrical Properties of Steels.* **R. Hadfield** and **E. Newbery.** (Roy. Soc., Proc. 93. pp. 56–67, Feb. 1, 1917.)—The condition that zinc should dissolve in acid may be expressed in the following form: single potential of metal + overvoltage < single potential of hydrogen electrode. In a mixture of zinc sulphate and sulphuric acid the potential of zinc will increase with increase in the concentration of zinc sulphate and the potential of the hydrogen will decrease as the acid concentration decreases, so that the conditions may be adjusted until the above statement becomes an equation. If a definite solution be used for a series of experiments, then the potential of the hydrogen electrode is constant and the tendency towards solution will be measured by the potential of the hydrogen electrode minus the sum of the overvoltage and the potential of the metal. Denoting the difference of these two values, the solution voltage, by S the condition that the metal shall dissolve with evolution of hydrogen is $S > 0$ and the rate of solution is proportional to the value of S. Assuming that the corrosion factor of a given steel is proportional to its rate of solution in a given acid and that the rate of corrosion without gas evolution is controlled by similar laws to that with gas evolution, it should be possible to estimate the corrosion factor of a given steel by measuring the overvoltage and single potential in a given acid, and the authors have examined 15 varieties of pure iron, carbon steel and alloy steels, with a view to determining the justifiability of these assumptions. The measurements were made in an electrolyte of N/1 sulphuric acid, and the sum of the overvoltages and the single potentials was taken as a measure of the resistance to corrosion. Study of the results show that in 4 cases out of 15 the results of the electrical method agreed with those of the atmospheric corrosion tests, while in only one case did the results of the acid corrosion test agree with those of the atmospheric test. It is evident therefore that with the electrolyte used the assumptions made are somewhat wide of the mark, but better results might be obtained with other electrolytes. F. C. A. H. L.

564. *Spontaneous Generation of Heat in recently Hardened Steel.* **C. F. Brush** and **R. A. Hadfield.** (Roy. Soc., Proc. 93. pp. 188–211, April 2,

1917.)—Shows that various kinds of steel, including carbon tool-steel, high-speed tungsten-chromium steel, and similar steels, after being quenched at a high temperature and hardened, spontaneously generate heat for at least several weeks in appreciable and measurable quantity, the rate of generation steadily diminishing.

The apparatus used by each author is described and consists of two vacuum jars, well insulated, into one of which the hardened specimens are placed, suitable arrangements being made to take the temperature at definite intervals.

In the case of Hadfield's experiments a pair of specimens of the same steel were taken. One was cooled in running water and transferred to one of the flasks, a mercurial thermometer being placed in the piece and the flask filled with magnesia. The second piece was heated to the desired quenching temperature and dropped into the quenching medium; after exactly two minutes it was removed and placed in the same running water as the previous specimen. When it had reached the same temperature as the first specimen it was transferred to the second flask, a similar thermometer being placed in the piece and the flask filled with magnesia. The temperature readings were taken at definite intervals for several hours. Tables are given showing the results obtained with nickel-chrome and other steels, in one case an actual rise of 1·1 deg. C. being noted.

The evolution of heat is very much more rapid immediately after quenching than later on. Water-quenched specimens show a larger evolution of heat than the same specimens after oil-quenching. [See also Abs. 1783 (1915) and paper by C. F. Brush, Phys. Rev. 9. pp. 228–236, March, 1917.]

C. O. B.

565. *Action of Light and of X-rays on Iodine and Starch Iodide.* **H. Bordier.** (Comptes Rendus, 163. pp. 205–206, Aug. 21, 1916.)—Light acting on iodine solutions causes the solutions to lose their colour. The solutions should be highly diluted: 10 drops of a 10 % alcoholic solution of iodine are added to a litre of water, or 3 drops of the alcoholic solution to a litre of water containing a little starch paste. An exposure to sunlight for a few hours is needed; no discolouration takes place in the dark, but light passed through a yellow filter retains its activity, and in the case of the starch solution the subsequent addition of a trace of iodine restores the colour. Some hydriodic acid seems to be formed by the light since the discoloured solutions react acid.

(Ibid. pp. 291–293, Sept. 18, 1916.)—In making the experiments with X-rays, four drops of the solution are used, so that there is 0·0072 gm. of iodine per litre. The solution is placed in a hermetically-sealed box of paraffined cardboard, the X-rays absorbed being determined with the aid of one of the author's chromoradiometer tabloids. The effect of the X-rays is much more powerful than that of light, the X-rays doing in 8 or 10 mins. what ultra-violet light does in 2 or 3 hours. The amount of X-rays required varies as the concentration of the iodine. When the X-rays are insufficient, and the discolouration is incomplete, complete discolouration may soon follow if the solution is left to itself, even in the dark. The effect might be utilised for quantitative radiotherapeutics.

H. B.

566. *Investigations upon Abnormal Electrolytic Dissociation.* **A. N. Sakhanow.** (J. Phys. Chem. 21. pp. 169–189, March, 1917.)—The conductivity of solutions of silver nitrate in the following solvents has been

determined: aniline, mixture of 4 vols. of aniline and 1 vol. of pyridine, quinoline, mixture of 1 vol. of aniline and 1 vol. of pyridine, pyridine, *m*-chloroaniline, mixture of 2 vols. of pyridine and 1 vol. of acetonitrile, acetonitrile, mixture of 1 vol. of acetonitrile and 1 vol. of water, water. The dielectric constants of the above solvents increase in the order given from 6·85 to 81·7 When the molecular conductivities are corrected for the viscosities of the solutions, it is found that the curves giving the relation between the concentration and the molecular conductivity show minima in all the solvents with dielectric constants between 6 and 82, the position of these minima being determined by the dielectric constant of the solvent. Abnormal dissociation, that is, decrease in the molecular conductivity with increasing dilution, decreases with increase in the dielectric constant of the solvent. It is only for solvents with low dielectric constants that abnormal dissociation is a very characteristic property. It is further found that maxima of molecular conductivity occur in solvents with dielectric constants up to 10. Walden's equation, $D\sqrt[3]{(V_m)} = \text{const.}$, holds with solvents having dielectric constants up to 35, when the corrected molecular conductivities are used.

Investigation of the transport number of silver in three of the above solvents, using a Nernst-Loeb apparatus, showed that in dilute solutions it was independent of the nature of the solvent. The more dilute the solution the more closely the transport number approaches the value of 0·47, but generally speaking it is considerably smaller for the solvents tested than for water. To explain the observed results it is assumed that associated molecules of the solute are formed in solution, which molecules then dissociate, giving complex anions as well as kathions.

Measurements of the e.m.f.'s of concentration cells of silver nitrate in pyridine showed that Nernst's theory can be applied to such solutions; also, that the degree of dissociation of silver nitrate in pyridine solution passes through a minimum, in accordance with the results of conductivity measurements. T. S. P.

567. *Passive State of Metals.* **C. W. Bennett** and **W. S. Burnham.** (Am. Electrochem. Soc., Trans. 29. pp. 217–254; Disc., 255–268, 1916. J. Phys. Chem. 21. pp. 107–149, Feb., 1917.)—The authors give a review of the work hitherto published on the passive state of metals, and after submitting the various theories of passivity to a critical examination come to the conclusion that they are all unsatisfactory. It is known that oxidising conditions develop passivity, whereas reducing conditions develop activity. Also, in alkaline solutions passivity is often accompanied by the formation of a visible film over the surface of the anode, and there are no facts known which support the view that passivity is due to one cause in alkaline, and to another cause in acid solutions. In all cases passivity is due to oxidation, and it is shown that this oxidation does not take place in the sense of (1) increasing the valence, (2) removing hydrogen, or (3) adding oxygen as a film. It follows that passivity is due to the formation of a film of oxide over the surface of the metal, and it is considered that the oxide is adsorbed by the metal and protects the surface of the latter. This oxide is not necessarily one of the known stable oxides; it may be unstable under ordinary conditions, but adsorption by the metal renders it stable. Reasons are given for assuming that the oxide in the case of chromium is not higher than CrO_3, being probably $CrCrO_4$ or CrO_2; similarly, in the case of iron it is not higher than FeO_3 and is possibly FeO_2. In the case of lead it has been

shown that passivity may occur where there is no visible film of oxide, and that the action of the lead under these conditions is similar to that of the same metal coated with a visible film of the oxide.

By means of the above theory of passivity the authors are able to explain many of the conflicting results hitherto obtained. T. S. P.

568. *Electrolytic Formation of Perchlorate.* **E. L. Mack.** (Am. Electrochem. Soc., Trans. 29. pp. 329–346, 1916. J. Phys. Chem. 21. pp. 238–264, March, 1917.)—The usual explanation given of the electrolytic formation of perchlorate is based on the assumption that chlorate cannot be directly oxidised to perchlorate. It presupposes the liberation of the chlorate ion which then gives chloric acid with the water. The chloric acid then decomposes into perchloric acid and chlorous acid, the latter being immediately oxidised to chloric acid by the oxygen liberated by the reaction : $2ClO_3 + H_2O = 2HClO_3 + O$. The author now demonstrates that in all probability the formation of perchlorate is due to direct oxidation at the anode. In the first place it is shown that perchlorate is formed at the anode at a potential far below that necessary for the continuous discharge of any ion present in the solution ; the oxidation is brought about by "active oxygen" (atomic oxygen) which is produced in sufficient concentration at the node without the potential rising high enough to bring about the liberation of molecular oxygen. In the second place it is shown that chlorate may be oxidised to perchlorate in aqueous solution by ordinary chemical methods, as, for example, by persulphates, especially in the presence of silver salts, by ozone, and by hydrogen peroxide in acid solutions. Oxidation may also be brought about by oxygen activated by ultra-violet light. T. S. P.

569. *Electrometric Titration of Zinc with Ferrocyanide.* **F. R. v. Bichowsky.** (Washington Acad. Sci., J. 7. pp. 141–143, March 19, 1917.)—When a solution of potassium ferrocyanide containing a Pt electrode is titrated with a solution of a zinc salt, the e.m.f. of the electrode being measured against a standard electrode, the titration follows a perfectly normal course, the e.m.f. increasing very sharply (to −0·40 volt against a normal calomel electrode) so soon as the least excess of zinc salt is added, so that the electrometric end-point is very sharp. When, however, the process is reversed, the ferrocyanide being run into the solution of the zinc salt, the reverse of the previous e.m.f. curve is not obtained unless the electrode has previously been adjusted to an e.m.f. of −0·45 volt. Almost any form of reverse curve may be obtained by adjusting the preliminary e.m.f. of the electrode or by stirring, but in all cases, except with no stirring, the reverse curve intercepts and then coincides with the normal curve before the end-point is reached. The electrometric titration is more rapid, convenient, and accurate than the ordinary titration with chemical indicators. T. S. P.

570. *The Electromotive Behaviour of Lead.* **P. Günther.** (Phys. Zeits. 18. p. 115, March 1, 1917. Paper read before the Deutsche Bunsen Gesell., Dec., 1916.)—For potential measurements of lead it is most convenient to deposit the Pb electrolytically on Pt-wire from very dilute lead-acetate solution by very weak currents. The potentials determined in couples: $Pb|PbCl_2$ saturated$|AgCl|Ag$ and $Pb|PbCl_2$ satur.$|Hg_2Cl_2|Hg$ agreed well with the thermal calculations of Brönsted [see Abs. 1022 (1914)]. The resulting heat of formation of lead chloride would be 85,400 or 85,380 cals., whilst Koref and Braune found 85,570 in calorimeter experiments. H. B.